ISSN: 2357-0547 (Print)
ISSN: 2357-0539 (Online)

Review Article / JAPR
Youssif et al., 2019, 3 (4), 158-181

Journal of Advanced Pharmacy Research 1

A Phytochemical and Biological Review on Plants of the Family Aizoaceae 2

Khayrya A. Youssif[1], Ali Elshamy[2], Mohamed A. Rabeh[1,2], Nagwan M. Gabr[3], Eman G. Haggag[*] 3

[1]*Department of Pharmacognosy, Faculty of Pharmacy, Modern University for Technology and Information, Cairo, Egypt,* [2]*Department of Pharmacognosy, Faculty of Pharmacy, Cairo University, Cairo, Egypt,* [3]*Department of Pharmacognosy, Faculty of Pharmacy, Helwan University, Cairo, Egypt, 11795.* 4

***Corresponding author:** *Prof. Dr. Eman Gaber Haggag, Department of Pharmacognosy, Faculty of Pharmacy, Helwan University, Cairo, Egypt, 11795 Tel. +201000023022*
Email address: wemisr@gmail.com 5

Submitted on: 26-04-2019; Revised on: 12-06-2019; Accepted on: 18-06-2019 6

To cite this article: Youssif, K. A.; Elshamy, A.; Rabeh, M. A.; Gabr, N. M.; Haggag, E. G. A Phytochemical and Biological Review on Plants of the Family Aizoaceae. *J. Adv. Pharm. Res.* **2019**, *3* (4), 158-181. DOI: 10.21608/APRH.2019.12303.1083 7

ABSTRACT 8

Objectives: This study is aimed to be a comprehensive review of the phytochemical constituents and biological activities of Aizoaceae family plants (Mesembryanthemaceae). **Methods:** This study is covering articles between 1969 and 2018, reviewed from internationally accepted databases and scientific data from scientific Journals. **Results:** Phytochemically studied plants of family Aizoaceae have shown the presence of various classes of compounds including; alkaloids, triterpenes, sterols, lignans, phenolic compounds, betacyanins, and essential oils. Biological studies on plants of family Aizoaceae have indicated various bioactive potentials including antioxidant, antidiabetic, antimicrobial, antitumor, hepatoprotective, anti-inflammatory and other effects. The reported medicinal plants of family Aizoaceae were selected and summarized on the basis of their; phytochemical constituents and biological activities. **Conclusion:** The results of this study may inspire further ethno-botanical and ethno-pharmacological research and investigations toward drug discovery. 9

Keywords: *Aizoaceae; Biological activities; Phytochemical constituents* 10

INTRODUCTION 11

The Aizoaceae (Mesembryanthemaceae) family is mostly composed of succulent plants of which 99% are found in South or Southwest of Africa. The other one-percent are found in coastal areas of Australia, New Zealand, Mediterranean area, Canary Islands, and the western coasts of Chile and California[1]. 12

Family Aizoaceae constitutes a major part of the Southern African succulent flora. With approximately 1860 species in 127 genera, and in India the family is represented by three genera, namely, *Sesuvium*, *Trianthema* and *Zaleya* with seven species distributed in the coastal and lowland areas of peninsular India and the Gangetic plains[2]. It is also South Africa's second largest plant family[3]. Based on the division given by Bittrich & Hartmann[4], five subfamilies are recognized: Aizooideae, Mesembryanthmoideae, Rushioideae, Sesuvioideae and Tetragonioideae[5]. In Egypt, Boulos[6] recognized five genera, but Hosny[7] listed only four genera without considering *Sesuvium*. According to Boulos[6] and Hosny[7], Trianthema is represented in Egypt by two species: *T. portulacastrum* L. and either *T. triquetra* Willd. Ex Spreng. (according to Boulos[6]) or *T. Crystalline* (Forssk.) Vahl (according to Hosny[7]). *Zaleya* is represented by two species: *Z. pentandra* (L.) C. Jeffrey and *Z. decandra* (L.) Burm. f.[6], or by only 13 14

one species: *Z. pentandra* (L.) C. Jeffrey[7]. This family is represented in Egypt by 6 genera and 10 species[8]. It typically inhabits dry subtropical deserts and wet tropical coasts[5-9]. Native species of Aizoaceae are distributed through Mediterranean coastal habitats and the Nile Valley as weeds of cultivated land, and extend to deserts.

Many members of the family are of economic importance as ornamentals and in cultivation worldwide[10] as some of them are used to stabilize sand dunes in coastal regions [11] while others are important as medicinal plants[12] e.g. *Tetragonia tetragonioides* is used in treatment of enteritis and stomach ache as well as stomach cancer and ulcer[12]. Extracts from these plants are used as preservatives, as a remedy against throat infections and in soap making[13]. Although Aizoaceae is considered as one of the most diverse and abundant families, it was found that it is the least studied in terms of medicinal potential[14]. It would, therefore, be important to extensively investigate other plants of family Aizoaceae for future drug discovery. Thus, we aimed to make a comprehensive review of the chemical constituents and biological activities of family Aizoaceae covering the articles between 1969 and 2018.

MATERIAL AND METHODS

The research strategy employed in the review of family Aizoaceae includes internationally accepted databases like Science Direct, Scopus and Web of Science as well as scientific data collected from scientific Journals.

RESULTS AND DISCUSSION

Phytochemical constituents

A variety of chemicals have been isolated from different species of family Aizoaceae including; alkaloids, triterpenes, sterols, lignans, flavonoids, phenolic compounds, essential oils, and some miscellaneous compounds[5-15-16].

Alkaloids

Mesembrine alkaloids are considered to be the primary active constituents of the South African medicinal plant *Sceletium tortuosum* Aizoaceae), and it is used as the dried or fermented aerial material from the plant, which is known as Kanna (Aka, Channa, Kougoed). Traditional regional use ranged from relieving thirst, mild analgesia, and alteration of mood[19]. Only two genera of family Aizoaceae were reported to be rich with alkaloids which are genus *Sceletium* and genus *Trianthema* as shown in **Table 1**. *Sceletium spp.* is currently the only known genus having species with relatively high levels of mesembrine[19], which belong to the crinane class of compounds based on the alkaloid skeleton[17]. Jeffs et al. (1982) categorized the various *Sceletium* alkaloids into four structural groups: (1) the 3a-aryl-*cis*-octahydroindole class (e.g. mesembrine and the new isolated alkaloid channaine)[17-18], (2) C-seco mesembrine alkaloids (e.g. joubertiamine), (3) alkaloids containing a 2,3 disubstituted pyridine moiety and 2 nitrogen atoms (e.g. *Sceletium* alkaloid A4) and (4) a ring C-seco *Sceletium* alkaloid A4 group (e.g. tortuosamine)[20]. The mesembrine alkaloid is the most studied of the mesembrine alkaloids due to its relative abundance in *S. tortuosum* and biological activity, it was initially partially isolated, characterized, and named by Zwicky, and it was purified and crystallized as picrate[19]. Mesembranol and its acetylated derivative, 4-*O*-acetylmesembrenol was also isolated together with 4-*O*-demethylmesembrenol and 4-*O*-demethylmesembranol from *Sceletium spp* in addition to mesembrenone. Joubertiamine and its derivatives represented a new structural class different from the known mesembranes. Joubertiamine, dehydrojoubertiamine, and dihydro-joubertiamine were all referred to as the seco-mesembranes and were isolated from *Sceletium joubertii*[17]. The preponderance of research on *Sceletium* alkaloids has revolved around isolation and structural elucidation. Very little is known about the distribution and chemotaxonomic patterns of these alkaloids within the genus[17].

Di-, Tri-, tetra-terpenes, and sterols:

Phytochemical screening and analysis of some species of family Aizoaceae showed presence of di-, tri, and tetraterpenes. β- amyrin, oleanolic acid, Uvaol were isolated from the leaves' methanolic extract of *C. edulis*[16], while ecdysterone, were isolated from aqueous and organic extracts of *S. portulacastrum*─and *T. portulacastrum*[15-24] Pentandradione and pentandraone were isolated only from the methanolic extract of *Z. pentandra*[50-51].

Sterols and their glycosides e.g. (Stigmasterol, β-Sitosterol, Stigmasterol 3-*O*-β-D-glucoside and β-Sitosterol 3-*O*-β-D-glucoside and the novel and recently isolated sterol 17-(5-ethyl-6-methylheptan-2-yl)-4,4,10,13-tetramethyl-hexadecahydro-1H-cyclopenta (α) phenanthren-3-ol) have been reported to be isolated from *T. portulacastrum*[15-16-21-22-24-25-26-27-28] as shown in **Table 2.**

Lignans and neolignans:

Aptenia cordifolia and *T. turgidifolium* leaves are the only reported member of family Aizoaceae to show the presence of lignans and neolignans e.g. Pinorsinol, syringaresinol, di-erythro-syringylglycrol-β-*O*-4,4`-syringarsinol ether and apteniol A-G were isolated from the methanolic extract of the leaves of *A. cordifolia*[22-29-30-31]. Isoamericanin A was isolated from *T. turgidifolium* [22] as shown in **Table 3.**

Table 1. Alkaloids isolated from plants of family Aizoaceae

Source	Used part/extract	Chemical constituents	Compound no.
Sceletium spp. *Sceletium tortuosum* (L.) N. E. Br. *Sceletium joubertii* L. Bolus	Acid-base extraction of the entire plant	- Δ^7 mesembrenone[17] - 4`-*O*-demethylmesemranol[17] - Mesembrenol[17] - Mesembranol[17] - 4`-*O*-demethylmesemrenone[17] - Sceletenone[17] - *N*-demethyl-*N*-formyl mesembrenone[17] - *O*-acetylmesembrenol[17] - Mesembrane[17] - *N*-demethylmesembrenol[17] - *N*-demethylmesembranol[17] - Hordenine[17]	1 ⟶ 12
Sceletium spp. *Sceletium tortuosum* (L.) N. E. *Sceletium joubertii* L. Bolus	Acid-base extraction of the entire plant	- Dehyrojoubertiamine[17] - Dihyrojoubertiamine[17] - Joubertiamine[17] - Joubertinamine[17] - *O*-methyldehydro-joubertiamine[17] - *O*-methyljoubertiamine[17] - *O*-methyldihydro-joubertiamine[17] - 3`-methoxy-4`- *O*-methyljoubertiamine[17] - 4-(3,4-dimethoxyphenyl)-4-[2-acetyl methylamino) ethyl]cyclohexanone[17] - 3`-methoxy-4`- *O*-methyljoubertiaminol[17] - 4-(3-methox-4-hydroxyphenyl)-4-[2-(acetylmethylamino) ethyl]cyclohexadienone[17] - 3a-(3,4-dimethoxyphenyl)-1-methyl-1,2,3,3a,4,5,6,8,9,9b-decahydro-7H-pyrrolo[2,3-f] quinolin-7-one[17] - Sceletium alkaloid A4[17] - Touruosamine[17] - *N*-formyltortuosamine[17] - *N*-acetyltortuosamine[17] - Mesembrenone[17] - Channaine[18] - Mesembrine[17] - 4`- *O*-demethylmesemrenol[17]	13 ⟶ 32
T. decandra L.	Organic extracts of leaves, fruits and seeds	-Trianthemine[22]	--------
T. portulacastrum L.	Organic extracts of the entire plant	- Punarnavine[23] - Trianthemine[23]	33
Sesuvium portulacastrum L.	Aqueous, methanolic and organic extracts of the whole dried plant	- Capsaicin[21-25]	34

Table 2. Reported plants of family Aizoaceae showing sterols, di-, tri-, and tetra-terpenes: 1

Reported Source	Used part/extract	Chemical constituents	Compound no.
Carpobrotus edulis L. Bolus	Methanolic extraxct of the leaves	- β- amyrin[16] - Oleanolic acid[16] - Uvaol[16]	35 → 37
Sesuvium portulacastrum L.	Aqueous, ethanolic and dichloromethane extracts of leaves and stems	- Ecdysterone[15] - Ecdysone[15] - 22,23-Dihydrostigmasterol[21-25] - Ethyl iso-allocholate[26] - Squalene[26] - Phytol[26]	38 → 43
- *Trianthema decandra* L.	Leaves, fruits and seeds organic extracts	- 3-Acetyl aleuritolic acid[22] - Stigmasterol 3- *O*-β-D-glucoside[22] - β-Sitosterol 3- *O*-β-D-glucoside[22] - Trianthenol[22]	44 → 47
Trianthema portulacastrum L.	Organic extracts of the aerial parts	- Ecdysterone[24] - 3-Acetyl aleuritolic acid[24] -Stigmasterol[24] - β-Sitosterol[24] - Stigmasterol 3- *O*-β-D-glucoside[24] - β-Sitosterol 3- *O*-β-D-glucoside[24] - Trianthenol[22-24] -17-(5-ethyl-6-methylheptan -2-yl)-4, 4, 10, 13- vetramethyl-hexadecahydro-1H cyclopenta(α) phenanthren-3-ol][27]	38 44 → 50
Zaleya pentandra L.	Methanolic extract of the aerial parts	- Pentandradione[28] - Pentandraone[28]	51, 52

Fatty acids, and fatty alcohols: 3

Sesuvium portulacastrum is the only member 4 of family Aizoaceae with data reported on isolates of fatty acids and fatty alcohols as shown in **Table 4**. It showed the presence of; Linolenic acid, oleic acid, eicosyl ester, 9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)-, hexadecanoic acid ethyl ester, lauric acid, tridecanoic acid, myristic acid, pentadecanoic acid, palmitic acid, heptadecanoic acid, stearic acid, oleic acid, linoleic acid, nonadecanoic acid, arachidic acid, heneicosanoic acid, behenic acid, octadecanoic acid, 1-Docosanol and rhodopsin, which were isolated from dichloromethane extract of its leaves and stems[11-26-32-33].

Catechins and phenolic acids 5

Reported data showed that catechins and 6 phenolic acids were isolated from six members only of family Aizoaceae which are; *A. cordifolia*, *C. edulis*, *M. crystallinum*, *S. portulacastrum*, *T. decandra*, and *T. portulacastrum*[14-21-22-25-26-29-33-34-35-36]. It has been reported, that epicatechin was isolated from the organic extracts of the leaves of two different plant species *C. edulis* and *S. portulacastrum*[14-21-22-25-26-29-33-34-35-36]. On the other hand, we found, that 2,6-bis(1,1-dimethylethyl)-4-methylphenol is the only phenolic compound isolated from *M. crystallinum*. Other isolated 7 catechins and phenolic compounds are shown in **Table 5.**

Flavonoids 8

Several flavonoids were isolated from different 9 species of family Aizoaceae. Rutin was isolated from the leaves ethyl acetate extract of *C. edulis* and *Mesembryanthemum forsskaolii*. Moreover, the new compound C-methyl flavone was isolated from the organic extracts of the whole plant of the two species *T. portulacastrum* and *T. decandra*[11-22-24-34-37-38-39-40]. Moreover, 2-(3',4'dihydroxyphenyl) 3,5,7- trihydroxy-chromen-4 one was also isolated from *T. decandra*[40]. Other isolated compounds are shown in **Table 6.**

Betacyanin 10

The genus *Lampranthus* of family Aizoaceae 11 was observed according to the reported data in **Table (7)** to show the presence of betacyanins. This includes *Lampranhus peersu* and *Lampranthus sociorum*. Betanin was isolated from the two plant species *Drosanthemum floribundum* and *Lampranthus spp*. Also, dopaxanthin was the only betacyanin isolated from *Glottiphyllum longum*, while β-Cyanin was isolated from *T. portulacastrum*[24-41-42-43-44].

Table 3. Lignans, neolignans isolated from plants of family Aizoaceae 1

Species	Used part/extract	Chemical constituents	Compound no.
Aptenia cordifolia L.F.	Methanolic extract of the leaves	- Pinorsinol[29] - Syringaresinol[29] - Di-erythro-syringylglycrol-β-o-4,4`-syringarsinol ether[29] - Apteniol A, B, C, D, E, F – Apteniol G[30]	53 ⟶ 59
Trianthema turgidifolium F. Muell	Methanolic extract of the leaves	– Isoamericanin A[22]	

2

Table 4. Fatty acids and fatty alcohols isolated from plants of family Aizoaceae 3

Species	Used part/extract	Chemical constituents	Compound no.
Sesuvium portulacastrum L.	Dichloromethane extracts of leaves and stems	- Linolenic acid[11-32] - Oleic acid eicosyl ester[26] - 9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)-[26] -Hexadecanoic acid ethylester[26]	60 ⟶ 63
Sesuvium portulacastrum L.	Dichloromethane extracts of leaves and stems	- Lauric acid[32] - Tridecanoic acid[32] - Myristic acid[11,32] - Pentadecanoic acid[32] - Palmitic acid[11,32] - Heptadecanoic acid[32] - Stearic acid[32] - Oleic acid[11,26,32] - Linoleic acid[11,32] - Nonadecanoic acid[32] - Arachidic acid[32] - Heneicosanoic acid[32] - Behenic acid[11,32] - Octdecanoic acid[33] - 1- Docosanol[26] - Rhodopin[26]	64 ⟶ 79

4

Nitrogen containing compounds 5

The reported data showed that some nitrogen-containing compounds like 2-(dimethylamino)-1-phenylethanol, 3-(1H-inol-3-yl) propionic acid, 3-(1H-inol-3-yl)propionic acid methyl ester, (2S,E)-N-[2-Hydroxy-2-(4-hydroxyphenyl)ethyl] Ferulamide, (E)-N--[2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)-ethyl] ferulamide, and (E)-N-[2-(4-Hydroxyphenyl)-2-propoxyethyl] ferulamide has been isolated from the methanolic extract of *A. cordifolia*, in addition to many compounds e.g. Trans-4-hydroxyprolinebtaine, and Pyrrolo [1,2-A] Pyrazin-1,4-dione,hexahydro-3-(phenylmethyl) were isolated from aqueous and organic extracts of *S. porulacastrum*. Moreover, nicotinic acid is the only isolated nitrogen-containing compound isolated from *T. portulacastrum*[15-21-23-25-29-31-33]as shown in **Table 8**. 6

Essential oils 7

The available data reported that only the leaves of *S. porulacastrum* yielded oil via hydro-distillation which upon analysis using GC-MS showed the following composition: o-cymene, α-pinene, 2-β-pinene, trans-caryophyllene, 1,8- cineole, limonene, α-terpinene, α-terpinolene, camphene, (-)-bornylacetate, tridecane and α-humulene[21-45] as shown in **Table 9.** 8

Miscellaneous compounds: 9

It has been reported, that different miscellaneous compounds have been isolated from five different plants of family Aizoaceae including; *A. cordifolia*, *C. edulis*, *T. portulacastrum* and *S. portulacastrum*[16-23-24-26-29-33-46-47] as shown in **Table 10.** 10

Table 5. Catechins and phenolic acids and their esters isolated from plants of family Aizoaceae 1

Species	Used part/extract	Chemical constituents	Compound no.
Aptenia cordifolia L.F.	Methanolic extract of the leaves	- 4-hydroxybenzoic acid[29] - Dihyrocinnamic acid[29] - 4-hydroxy-dihydrocinnamic acid[29] - Dihydrofrulic acid[29] - 3,4-dimethoxy-dihyrocinnamic acid[29] -3,4-dimethoxy-dihyro cinnamic acid methyl ester[29] - 3,4-dimethoxy-dihyrocinnamic acid ethyl ester[29] - Methylfrulate[29] - Sinapic acid[29] - Methyl 2,5-dihyroxybenzoate[29] - 3,4,5-Trimethoxyphenol[29] - 3-Hydroxy-7,8-dihydro-β-ionone[29] - 3,4-dimethoxycinnamic acid[29]	80 → 85
Carpobrotus edulis L. Bolus	Leaves methanolic and ethylacetate extract	- Ferulic acid[34] - Catechin[14] - Epicatechin[14] - Procyanidin (B5)[14]	82 86 → 88
Mesembryanthemum crystallinum L.	Methanolic extract of the leaves	2,6-bis(1,1-dimethylethyl)-4-methylphenol[35,36]	89
Sesuvium portulacastrum L.	Aqueous, ethanolic and dichloromethane extracts of leaves and stems	- Epicatechin[21,25] - Phenol,2,4-bis(1,1-dimethylethyl)[33] - Gallic acid[21,25] - Benzoic acid[21] - Benzoic acid, 4-ethoxy-, ethyl ester[26]	87 90 → 93
Trianthema decandra L.	Leaves, fruits and seeds organic extracts	- 5- Hydroxy-2-methoxy benzaldehyde[22] - *P*-Methoxybenzoic acid[22] - *P*-Propoxybenzoic acid[22] - Leptorumol[22]	94 → 97
Trianthema portulacastrum L.	Organic extracts of the aerial parts	- 4-hydroxybenzoic acid[24] - 3,4-Dimethoxycinnamic acid[24,35] - Pyrogallol[24] - 5- Hydroxy-2-methoxy benzaldehyde[35] - Protocatechuic acid[24] - Vanillic acid[24] - *O*-Coumaric acid[24] - Caffeic acid[24] - *P*-Methoxybenzoic acid[24,35] - *P*-Propoxybenzoic acid[24,35] - Leptorumol[24]	80, 81 94 → 102

Biological activities: 3

Members of family Aizoaceae are known to have diverse biological activities including anti-hyperlipidemic, antipyretic, diuretic, antioxidant, anticancer, larvicidal, analgesic, anti-rheumatic, anticholera, emetic, laxative, anti-inflammatory andantimicrobial. As well as being used in the treatment of; skin diseases, specific blood diseases, jaundice, cataract, night blindness, heart diseases, joint pain, dropsy, ascites, edema, and others as shown in **Table 11.**

Antioxidant activity 5

Oxidative stress can cause damage to tissues and cells. Free radicals, such as nitric oxide, superoxide anions, and hydroxyl radicals, can result in oxidative stress and may inflict damage in almost every organ. Furthermore, cancers also can arise from excess reactive oxygen species (ROS) that can damage cellular DNA. The antioxidant potential of the following plant organic extracts: *T. portulacastrum*, *Mesembryanthemum forsskaolii*, *Aizoon canariense*,

Table 6. Flavonoids isolated from plants of family Aizoaceae 1

Species	Used part/extract	Chemical constituents	Figure no.
Carpobrotus edulis L. Bolus	Ethyl acetate extract of leaves	- Rutin[34] - Hyperoside[34] - Neohesperidin[34]	103, 104
Mesembryanthemum forsskaolii Hochst. ex Bioss	Methanolic extract of the entire herb	- Rutin[37] - Apigenin[37] - Apigenin-7-*O*-glucoside[37] - Kaempferol-3-*O*-glucoside[37] - Isorhamnetin-3-*O*-β-glucopyranoside[37]	103 105 → 108
Sesuvium portulacastrum L.	Aqueous, ethanolic and dichloromethane extracts of the leaves and stems	- 3,5,4`-trihyroxy-6,7-dimethoxyflavone[11] - 3,5-dihydroxy-6,3 ',4' -trimethoxy-flavone-7-0-[α-L-rhamnopyranosyl-1 (1—6)- β-D-Glucopyranoside[11]	103, 109
Trianthema portulacastrum L.	Organic extracts of the dried plant	- Quercetin[24] - C-Methyl Flavone[24,38] - 5, 2′-dihydroxy-7-methoxy-6, 8-dimethylflavone[39]	103, 110
Trianthema decandra L.	Leaves, fruits and seeds organic extracts	- C-Methyl Flavone[22] - 2 - (3', 4' dihydroxyphenyl) 3, 5, 7 - trihydroxy-chromen-4 one[40]	103, 111

2

Table 7. Betacyanins isolated from plants of family Aizoaceae 3

Species	Used part/extract	Chemical constituents	Compound no.
Drosanthemum floribundum (Haw.) N.E.Br.	Methanolic extract of the flowers	- Betanidine[41] - Isobetanidine[41] - Betanin[41] - Isobtanin[41]	112 → 115
Glottiphyllum longum (Haw.) N.E.Br.	Methanolic extract of the flowers	Dopaxanthin[42]	116
Lampranthus spp	Aqueous extract of the flowers	- Betanin[43] - Isobtanin[43]	114, 115
Lampranthus sociorum N.E.Br.	Methanolic extract of the flowers	Betanidin 5-0-[2"-*O*-(E)-feruloyl- β -(1",2')-glucuronosyl-β-glucoside][44]	117
Lampranhus peersii N.E.Br.	Methanolic extract of the flowers	Betanidin- 5-0-[6'- *O*-(E)-feruloyl- β-glucoside][44]	118
Trianthema portulacastrum L.	Organic extracts of the dried plant	β-Cyanin[24]	119

4

Mesembryanthemum Nodiflorum, Mesembryanthemum crystallinum, Mesembryanthemum forsskaolii, S. portulacastrum Mesembryanthemum nodiflorum, Carpobrotus edulis, Mesembryanthemum edule Mesembryanthemum crystallinum and *T. decandra* were investigated by 1,1-diphenyl-2-picryl hydrazyl (DPPH) and hydrogen peroxide assays. The results indicated that the organic extracts possessed a concentration-dependent free radical-scavenging activity against DPPH and hydrogen peroxide radicals, which was comparable with standard ascorbic acid[15-22-24-36-37-48-49-50]. 5

Anticancer activity: 6

The organic extracts of the following plants: *T. portulacastrum, S. portulacastrum, Carpobrotus edulis* and *T. decandra* showed anticancer activity against mouse lymphoma cells and hepatic carcinoma using MTT assay[16-22-24-33]. 7

The protective role of *T. portulacastrum* against diethylnitrosoamine–induced experimental hepatocarcinogenesis was evaluated. Morphometric evaluation of focal lesions showed a reduction of altered liver cell foci/cm^2 and a reduction of the average focal area. A decrease in the percentage of liver 8

Table 8. Nitrogen containing compounds isolated from plants of family Aizoaceae

Species	Used part/extract	Chemical constituents	Compound no.
Aptenia cordifolia L.F.	Leaves methanolic extract	- 2-(dimethylamino)-1-phenylethanol[29] - 3-(1H-inol-3-yl) propionic acid[29] - 3-(1H-inol-3-yl) propionic acid methyl ester[29] - (2S, E)-N-[2-Hydroxy-2-(4-hydroxyphenyl) ethyl] Ferulamide[31] - (E)-N-[2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)-ethyl] ferulamide[31] - (E)-N-[2-(4-Hydroxyphenyl)-2-propoxyethyl] ferulamide[31] - (E, E)-N,N-Dityramin-4,40 -dihydroxy-3,50 -dimethoxy-b,30 -bicinnamamide[31] - 7-Hydroxy-1-(4-hydroxy-3-methoxyphenyl)-N2, N3-bis(4-hydroxyphenethyl)-6-methoxy-1,2-dihydronaphthalene-2,3-dicarboxamide[31]	120 → 125
Sesuvium portulacastrum L.	Aqueous, methanolic and organic extracts of the whole dried plant	- Trans-4-hydroxyprolinebtaine[15] - Pyrrolo[1,2-A] Pyrazin-1,4-dione, hexahydro-3-(phenylmethyl)[33] - Pyrrolo[1,2-A] Pyrazin-1,4-dione, hexahydro-3-(2-methylpropyl)[33] - Butanoic acid, pyrolidide[33] - L-proline, N-Valeryl-, hexadecyl ester[33]	126 → 130
Trianthema portulacastrum L.	Organic extracts of the whole dried plant	- Nicotinic acid[23]	131

Table 9. Essential oils isolated from plants of family Aizoaceae

Species	Used part/extract	Chemical constituents	Compound no.
Sesuvium porulacastrum L.	Leaves hydrodistillation	- *O*-cymene[21,45] - α-Pinene[21,45] - 2-β-Pinene[45] - Trans-Caryophyllene[21,45] - 1,8- Cineole[21,45] - Limonene[21,45] - α-Terpinene[21-45] - α-Terpinolene[21,45] - Camphene[21,45] - (-)-Bornylacetate[21,45] - Tridecane[21,45] - α- Humulene[21,45]	132 → 143

Table 10. Miscellaneous compounds isolated from plants of family Aizoaceae

Species	Used part/extract	Chemical constituents	Compound no.
Aptenia cordifolia L.F.	Methanolic extract of the leaves	- 4-(hydroxymethyl) phenol[29] - 4-(hydroxymethyl)-2,6 dimethoxyphenol[29] - Dehydrololiolide[29] - (9R)-9-hyroxymegastigm-4-ene-3-one[29] - Mgastigm-4-ene-3,9-dione[29] - 4-oxo-7,8-dihydro-β-ionone[29] - (3R,9R)-3,9-dihyroxymegastigm-5-en-4-one[29] - 3-*O*-methyl-chiro-inositol[29]	144 → 149
Carpobrotus edulis L. Bolus	Methanolic extract of the leaves	Monogalactosyl diacylglycerol[16]	150
Trianthema portulacastrum L.	Organic extracts of the dried whole plant	- β-Carotene[24] - Ascorbic acid[23]	151, 152
Trianthema decandra L.	Methanolic extract of the leaves	Bis (2-ethyl hexyl) phthalate[46]	153
Sesuvium portulacastrum L.	Aqueous, methanolic and organic extracts of the dried plant	- Hentriacontane[33] - L-(+)-ascorbic acid,2-6-dihexaecanoate[33] - Vitamin E[26] - 1-monolinoleoylglycerol-trimethylsilyl ether[26] - Dibutylphthalate[47] - Diisooctyl phthalate[47]	154 → 159

parenchyma occupied by foci seems to suggest the anticarcinogenic potential of the plant extract in DENA-induced hepatocarcinogenesis[22].

Analgesic, antinociceptive, antihyperglycemic and hepatoprotectiveactivity

The methanol extract of the leaves of *T. portulacastrum* and *T. decandra* have remarkable analgesic, antinociceptive activity, antihyperglycemic and hepatoprotective activity[22-24].

The analgesic activity of the leaf extract of *T. decandra* was detected by hot plate and acetic acid-induced writhing response method. The results indicate that the administration of leaf extract of *T. decandra* exhibit central analgesic properties since it exerted a significant and dose-dependent effect on the chemical (acetic acid-induced) and thermic (heat) painful stimuli from the respective doses of 100 and 200 mg/kg[22].

Many natural plant extracts have been investigated with respect to the suppression of glucose production from carbohydrates in the gut or glucose absorption from the intestine.

α- amylase catalyzes the hydrolysis of α -1,4-glucosidic linkages of starch, glycogen and various oligosaccharides and α-glucosidase further breaks down the disaccharides into simpler sugars, readily available for the intestinal absorption. The inhibition of their activity, in the digestive tract of humans, is considered to be effective to control diabetes by diminishing the absorption of glucose decomposed from starch by these enzymes. Therefore, effective and nontoxic inhibitors of α - amylase and α-glucosidase have long been sought, and for the first time, studies have revealed the anti-diabetic potential of *T. decandra* and these studies could be helpful to develop medicinal preparations for diabetes[22].

The probable mechanism by which *T. portulacastrum* exerts its hepatoprotective action against paracetamol or thioacetamide-induced hepatocellular metabolic alterations could be by the stimulation of hepatic regeneration through an improved synthesis of protein or accelerated detoxification and excretion[22].

Anti-inflammatory activity

The anti-inflammatory activity of methanolic and organic extracts of the following plants: *T. portulacastrum*, *Aizoon canariense*, *Aizoon hispanicum*,

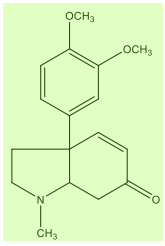
Table 11. Different plant species and their biological activities reported in family Aizoaceae 1

Plant name	Biological activities	References
Aptenia cordifolia L.F.	- Algicide activity - Antifungal	29
Aizoon canariense L.	- Antioxidant - Antibacterial - Skin diseases - Emetic - Antiiflammatory - Antifungal - Wound healing	48,51,52
Aizoon hispanicum L.	Antiiflammatory	51
Carpobrotus acinaciformis L.	Antidiarrhea and dysentery	50,53
Carpobrotus edulis L. Bolus	- Antioxidant - Anticancer - Antibacterial - Antidiarrhea and dysentery - Anti HFFIV/AIDS	16,34,35,53,54
Carpobrotus muirii L.	Antidiarrhea and dysentery - Antioxidant	53
Galenia Africana L.	- Antituberculosis - Asthma and obstructive pulmonary diseases	55
Gisekia phernaceoides L.	Antibacterial	56
Lampranthus francisci L. Bolus	Anticandidal	57
Mesembryanthemum anatomicum Haw.	- Mood altering - CNS stimulant	58
Mesembryanthemum crystallinum L.	- Antioxidant - Antifungal - Antibacterial	35,36,48,50
Mesembryanthemum forsskaolii Hochst. ex Bioss	- Antioxidant - Antibacterial - Antifungal	35,37
Mesembryanthemum nodiflorum L.	- Antibacterial - Antioxidant - Antifungal - Cytotoxic	35,49
Sceletium spp.	- Antiinflammatory - Asthma and obstructive pulmonary diseases - Cytotoxic - Psoriasis - Cocaine like activity - Antidepressant - Psychiatric conditions - Antianxiety	17,58
Sceletium tortuosum (L.) N. E. Br.	- Antidote in alcohol poisoning - Antidepressant - Psychiatric conditions - Antianxiety - Hypnotic and sedative	17,58,59
Sesuvium portulacastrum L.	- Antioxidant - Anticancer - Antifungal - Antibacterial - Antiulcerogenic - Kidney disorders	15,33

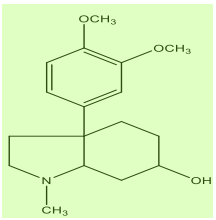
Table 11. Cont. 1

Sesuvium verrucosum Raf.	Cytotoxic	21
Trianthema decandra L.	- Antioxidant - Anticancer - Analgesic and antinociceptive - Antihyperglycemic - Hepatoprotective - Antiinflammatory - Antibacterial - Antifungal - Antiulcerogenic - Wound healing	22,40
Zaleya pentandra L.	- Antiacetylcholinesterase - Antibutyrylcholinesterase - Antifungal - Stomach diseases - Respiratory tract infection and cough - Asthma and obstructive pulmonary diseases - Laxative - Blood diseases - Jaundince - Larvicidal - Cataract and night blindness	28,60,61

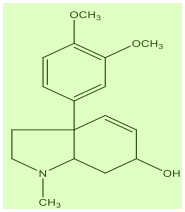
2


3

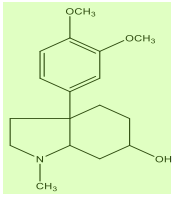
(1) Δ^7 Mesembrenone 4


5

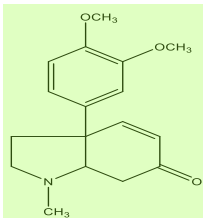
(2) 4`-*O*- demethylmesemranol 6


7

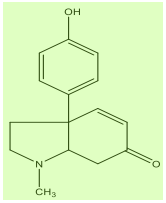
(3) Mesembrenol 8


9

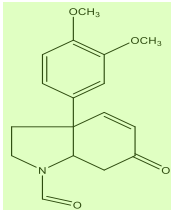
(4) Mesembranol 10


11

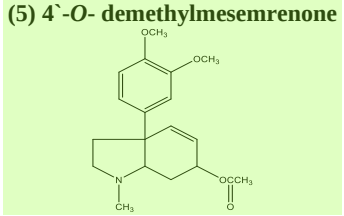
(5) 4`-*O*- demethylmesemrenone 15


12

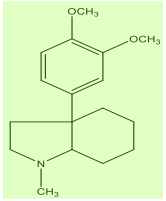
(6) Sceletenone 13


14

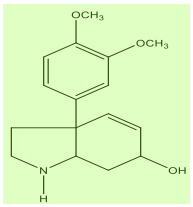
(7) *N*-demethyl-*N*- formyl mesembrenone 17



(8) *O*-acetylmesembrenol 18

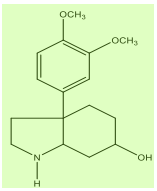

16

(9) Mesembrane 19



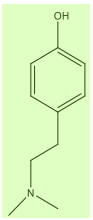
1

(10) *N*-demethylmesembrenol 2



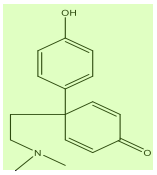
3

(11) *N*- demethylmesembranol 4



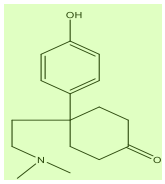
5

(12) Hordinine 6



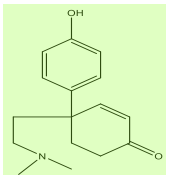
7

(13) Dehyrojoubertiamine 8



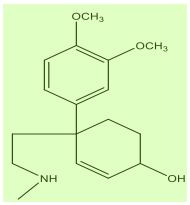
9

(14) Dihyrojoubertiamine 10



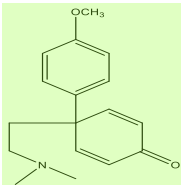
11

(15) Joubertiamine 12



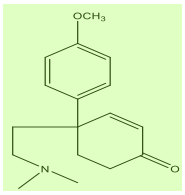
13

(16) Joubertinamine 15



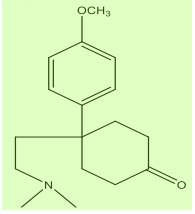
14

(17) *O*-methyldehydro joubertiamine 17



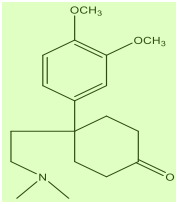
16

(18) *O*-methyl joubertiamine 18



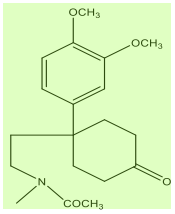
19

(19) *O*-methyl dihydrojoubertiamin 20



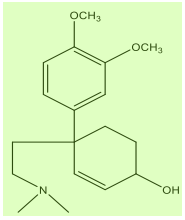
21

(20) 3`-methoxy-4`-o- methyl joubertiamine 22



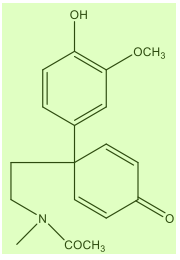
23

(21) 4-(3,4dimethoxyphenyl)-4 – [2-(acetyl methyl) amino] ethyl cyclohexanone 24



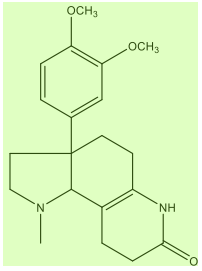
25

(22) 3`-methoxy-4`- *O*-methyl joubertiaminol 26



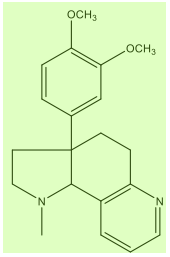
27

(23) 4-(3-methox-4-hydroxy phenyl)-4- [2 (acetyl methyl) amino] ethyl cyclohexanone 29



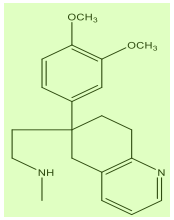
28

(24) 3a-(3,4-dimethoxy phenyl)-1-methyl1,2,3,3a,4,5,6,8,9,9b -decahydro-7H-pyrrolo[2,3-f] quinolin-7-one 30



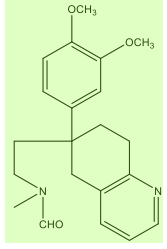
31

(25) Sceletium alkaloid A4 35



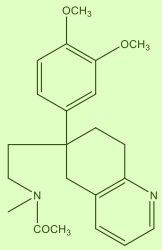
32

(26) Touruosamine 34

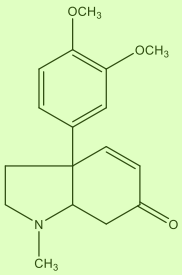


33

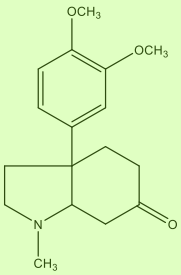
(27) *N*-formyl tortuosamine 36



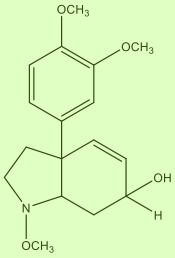
(28) *N*-acetyl tortuosamine



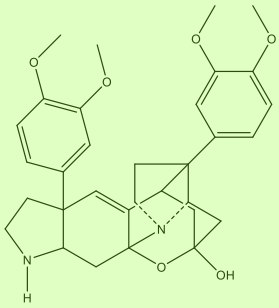
(29) Mesembrenone



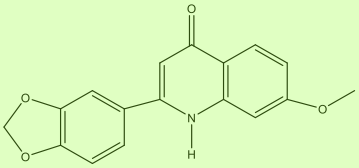
(30) Mesembrine



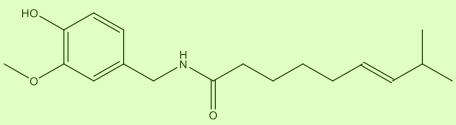
(31) 4`-*O*-demethylmesemrenol



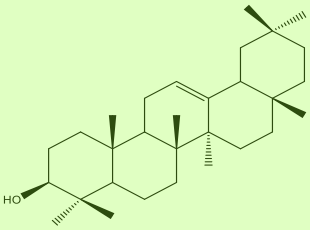
(32) Channaine



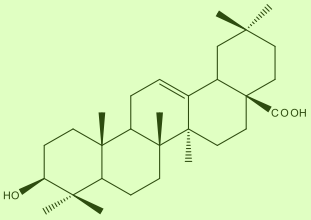
(33) Punarnavine



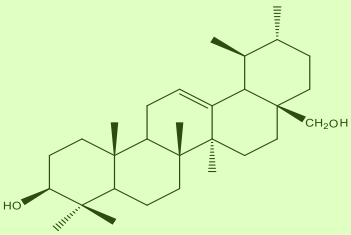
(34) Capsaicin



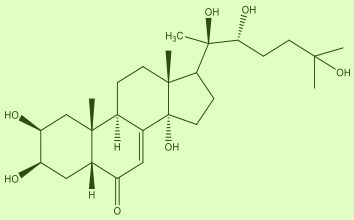
(35) β-Amyrin



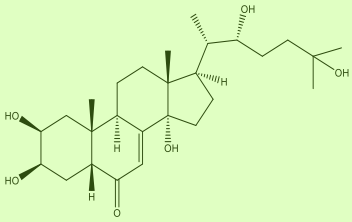
(36) Oleanolic acid



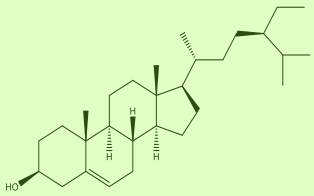
(37) Uvaol



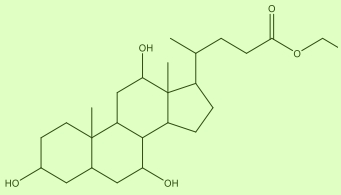
(38) Ecdysterone



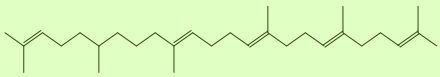
(39) Ecdysone



(40) 22, 23-Dihydrostigmasterol

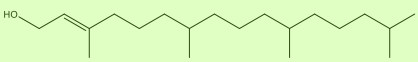


(41) Ethyl iso-allocholate

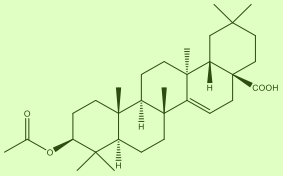


(42) Squalene

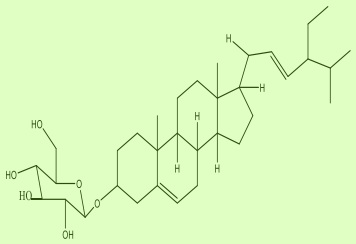
1



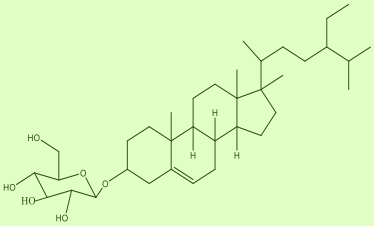
(43) Phytol



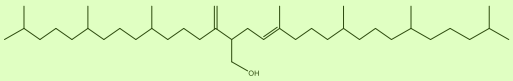
(44) 3-Acetyl aleuritolic acid



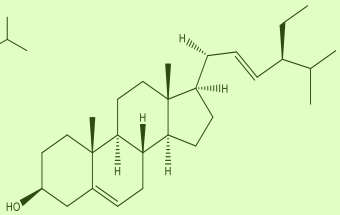
(45) Stigmasterol 3- *O*-β-D-glucoside



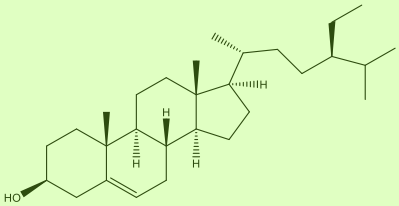
(46) β-Sitosterol 3- *O*- β-D-glucoside



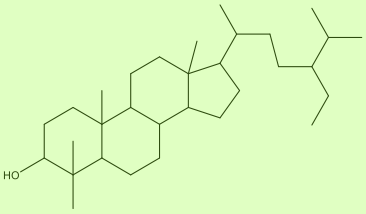
(47) Trianthenol



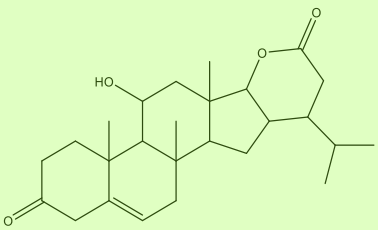
(48) Stigmasterol



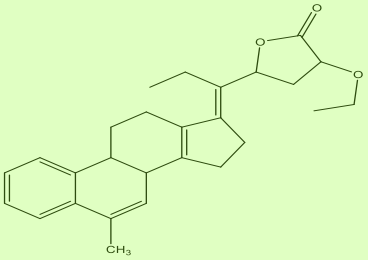
(49) β-Sitosterol



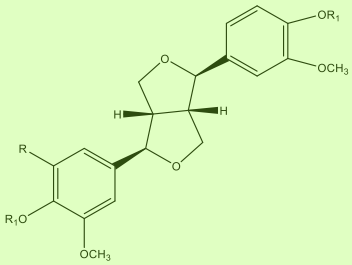
(50) 17-(5-ethyl-6-methylheptan -2-yl)-4, 4, 10, 13- vetramethyl-hexadecahydro-1H cyclopenta(α) phenanthren-3-ol]



(51) Pentandradione

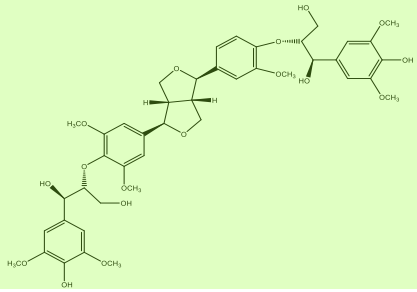


(52) Pentandraone



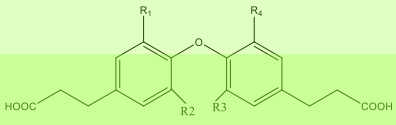
2

(53)	
Pinorsinol	R=R1=H
Syringaresinol	R=OCH_3, R1=H



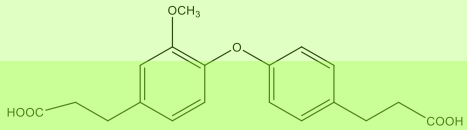
(54) Di-erythro-syringylglycrol-β-o-4,4`- syringaresinol ether 3

1

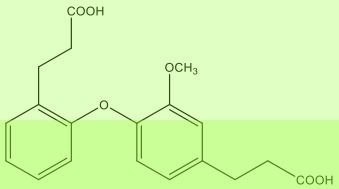


(55)

2

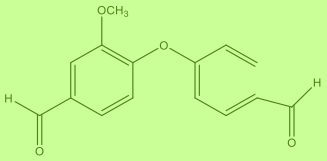


(56) Apteniol C

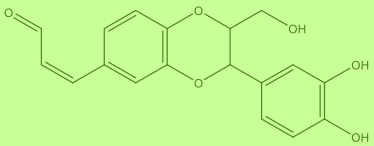


(57) Apteniol F

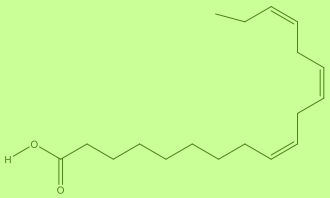
Apteniol A R1=R2=R3=R4
Apteniol B R1=OMe; R2=R3=R4=H
Apteniol D R1=R2=R3=OMe; R4=H
Apteniol E R1=R2=R3=R4=OMe



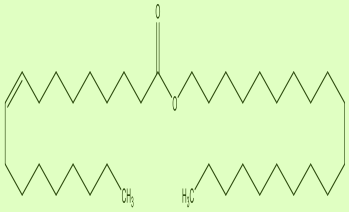
(58) Apteniol G



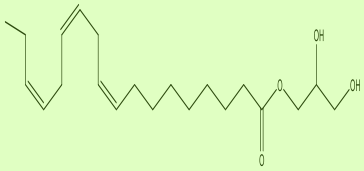
(59) Isoamericanin A



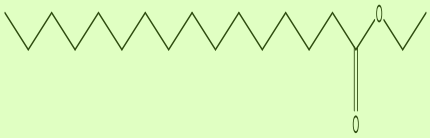
(60) Linolenic acid



(61) Oleic acid eicosyl ester

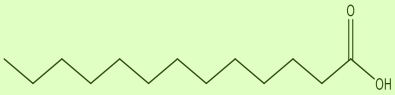


(62) 9,12,15-Octadecatrienoic acid 2,3-dihydroxy propyl ester

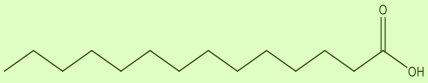


(63) Hexadecanoic acid ethyl ester

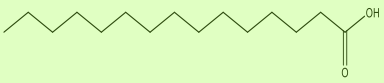
(64) Lauric acid



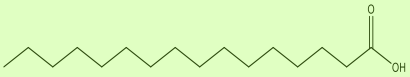
(65) Trideconaic acid



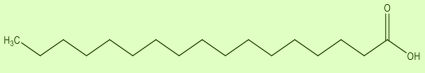
(66) Myristic acid



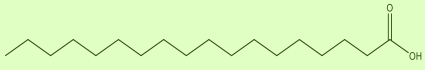
(67) Pentadecanoic acid



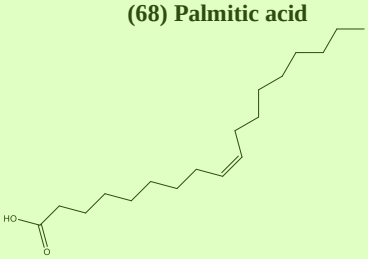
(68) Palmitic acid



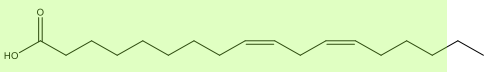
(69) Heptadecanoic acid



(70) Stearic acid

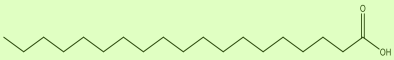


(71) Oleic acid



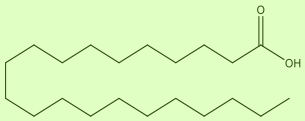
(72) Linoliec acid

1

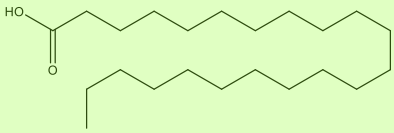


(73) Nonadecanoic acid

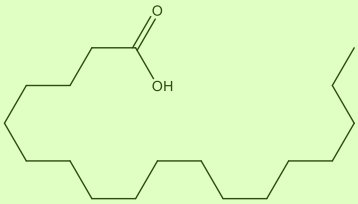
(74) Arachidic acid



(75) Heneicosanoic acid



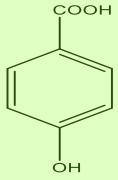
(76) Behenic acid



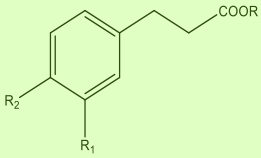
(77) Octadecanoic acid

(78) 1-Docosanol acid

(79) Rhodopin



(80) 4-hydroxy benzoic acid 3



(81) 2

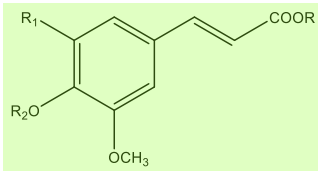
Dihyrocinnamic acid	$R=R_1=R_2=H$
4-hydroxy-dihydrocinnamic acid	$R=R_1=H$, $R_2=OH$

4

Dihydrofrulic acid	$R=H$, $R_1=OCH3$, $R_2=OH$

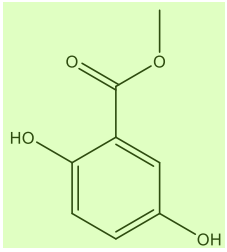
5

3,4-dimethoxy-dihyrocinnamic acid	6	$R=H$, $R_1=R_2=OCH3$	7
3,4-dimethoxy-dihyrocinnamic acid methyl ester	9	$R=CH_3$, $R_1=R_2=OCH_3$	8
3,4-dimethoxy-dihyrocinnamic acid ethyl ester	11	$R=CH_2CH_3$, $R_1=R_2=OCH_3$	10
3,4-dimethoxycinnamic acid		$R=H$, $R_1=R_2=OCH_3$	12

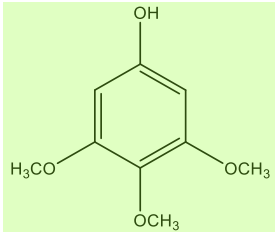


(82) 15

13



17



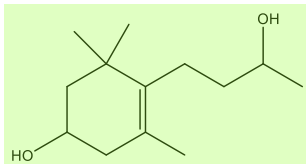
16

Ferulic acid	R=R1=R2=H
Methyl ferulate	$R=CH_3$, R1=R2=H
Sinapic acid	R=R2=H, $R1=OCH_3$
3,4,5 tri-methoxy cinnamic acid	R=H, $R1=OCH_3$, $R2=CH_3$

14

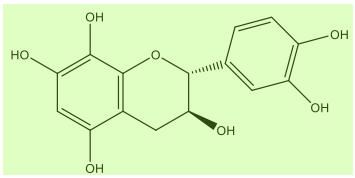
(83) Methyl 2,5-dihydroxybenzoate 18

(84) 3,4,5-Trimethoxyphenol 19



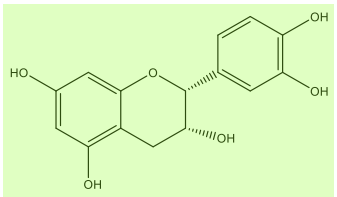
1

(85) 3-Hydroxy-7,8-dihydro-β-ionone 2



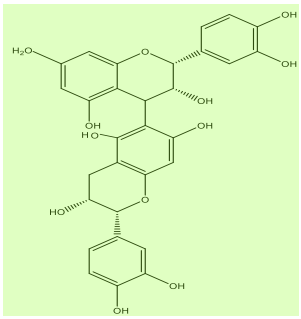
9

(86) Catechin 10



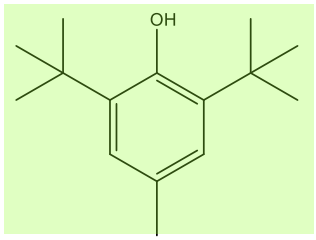
19

(87) Epicatechin



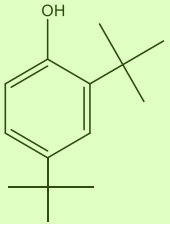
3

(88) Procyanidin

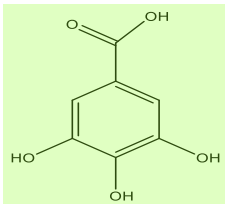


11

(89) 2,6-bis(1,1-dimethylethyl)-4-methylphenol 12

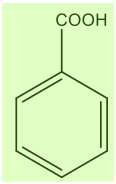


(90) Phenol 2,4-bis(1,1-dimethylethyl) 20



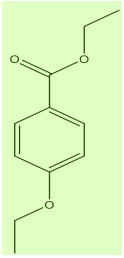
4

(91) Gallic acid 5



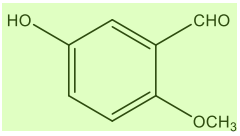
13

(92) Benzoic acid 14



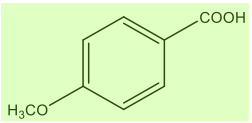
21

(93) Benzoic acid, 4-ethoxy ethyl ester 22



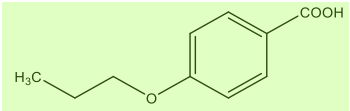
6

(94) 5-Hydroxy-2-methoxy benzaldehyde 7



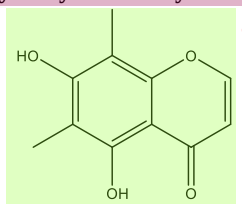
15

(95) *ρ*-methoxy benzoic acid 16



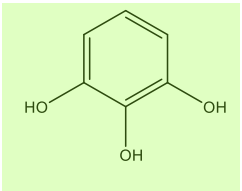
24

(96) *ρ*- propoxy benzoic acid



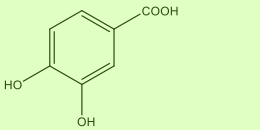
8

(97) Leptorumol

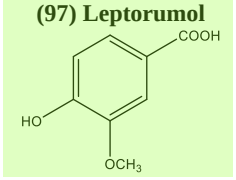


17

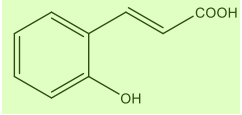
(98) Pyrogallol



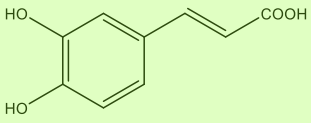
(99) Protocatechuic acid



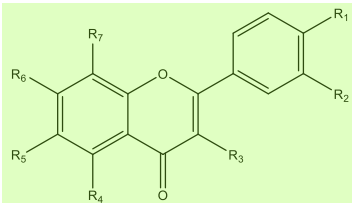
(100) Vanillic acid 23



(101) *O*- coumaric acid 18



(102) Caffeic acid 25

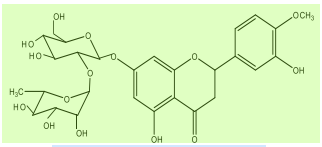


1

(103) 2

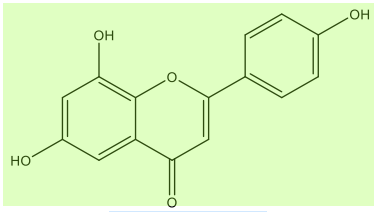
Compound	R1	R2	R3	R4	R5	R6	R7
Rutin	OH	OH	O-Rutinose	OH	H	OH	H
Quercetin	OH	OH	OH	OH	H	OH	H
3,5,4`-trihyroxy-6,7-dimethoxyflavone	OH	H	OH	OH	OCH3	OCH3	H
C-Methyl flavone	H	H	H	OCH3	CH3	OCH3	CH3
Hyperoside	OH	OH	O-Galactose	OH	H	OH	H

3



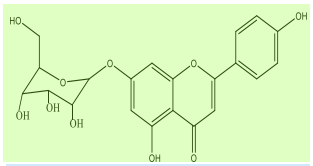
4

(104) Neohesperidin 5



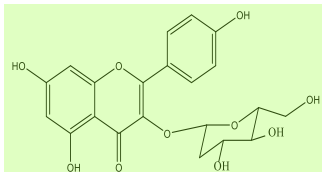
6

(105) Apigenin 9



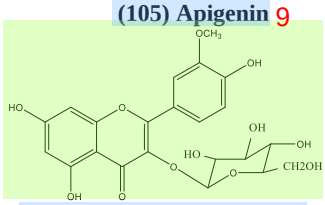
11

(106) Apigenin-7-*O*-glucoside 12



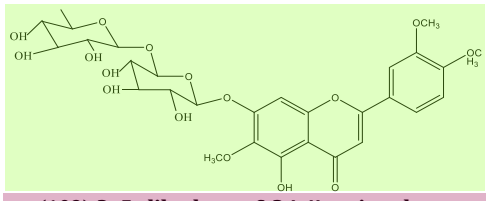
7

(107) Kaempherol 3- *O* – glucoside 8



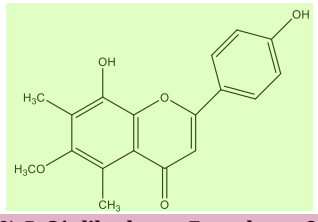
10

(108) Isorhamnetin -3 –*O*- β glucoside 14



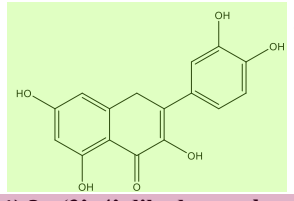
13

(109) 3, 5-dihydroxy-6,3 ',4' –trimethoxy flavone-7-0-[α-L-rhamnopyranosyl (1-6) – β-D – glucopyranoside 16



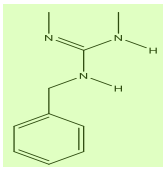
17

(110) 5, 2′-dihydroxy-7-methoxy-6, 8 – dimethyl flavone 18



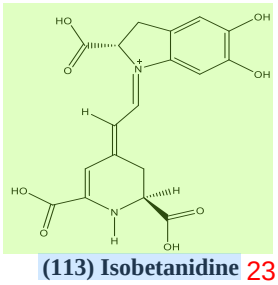
15

(111) 2 - (3', 4' dihydroxy-phenyl) - 3, 5, 7-trihydroxy-chromen-4-one 19



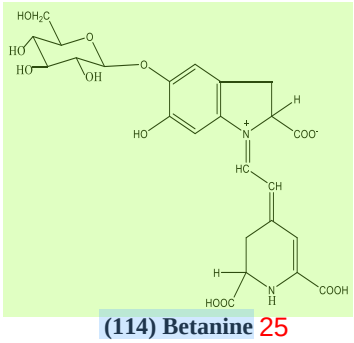
20

(112) Betanidine 21



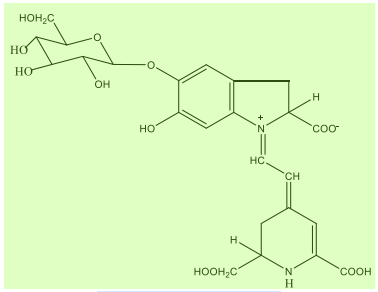
22

(113) Isobetanidine 23



24

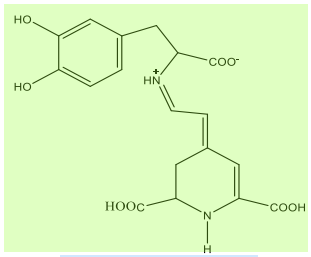
(114) Betanine 25



26

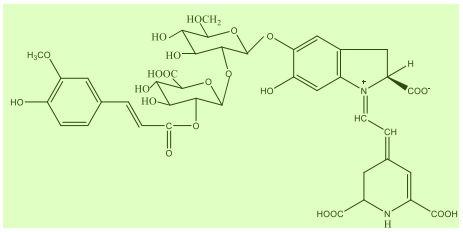
(115) Isobetanine 27

1



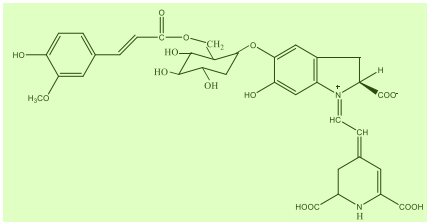
(116) Dopaxanthin 2

3



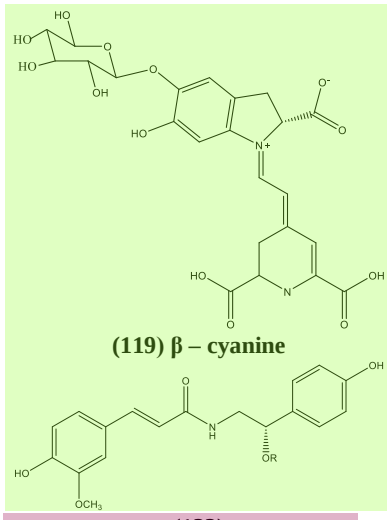
(117) Betanidin 5-*O*-[2"-*O*-(E)-feruloyl- β - (1",2')-glucuronosyl-β-glucoside] 4

5



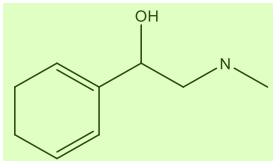
(118) Betanidin- 5-*O*-[6'- *O*-(E)-feruloyl- β-glucoside] 6

7



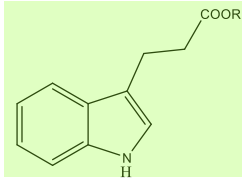
(119) β – cyanine

8



(120) 2-(dimethylamino)-1-phenylethanol 9

10



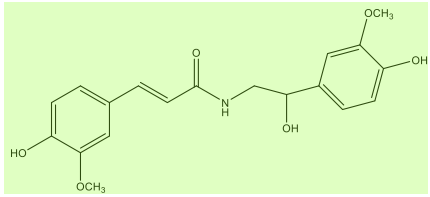
(121) 11

3-(1*H*-inol-3-yl) propionic acid R=H 12
3-(1*H*-inol-3-yl) propionic acid methyl ester R=CH_3

(122)
(2S, E)-N-[2-Hydroxy-2-(4-hydroxyphenyl) ethyl] ferulamide 13
R=H

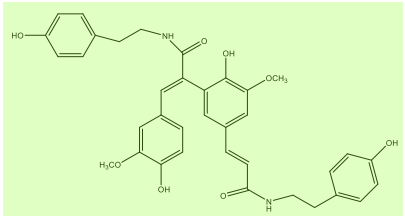
(E)-N-[2-(4-Hydroxyphenyl)-2-propoxyethyl] ferulamide R= n-Propyl 14

15



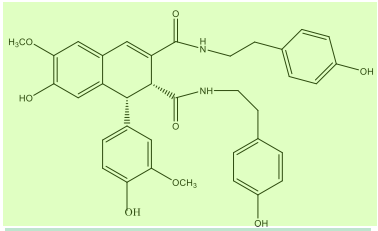
(123) (E)-N-[2-Hydroxy-2-(4-hydroxy-3-methoxyphenyl)-ethyl] ferulamide 16

17



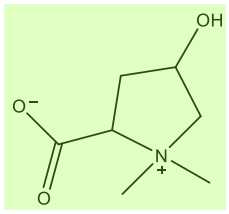
(124) (E, E)-N, N-Dityramin-4,40 -dihydroxy-3,50 - dimethoxy-b,30 -bicinnamamide 18

19



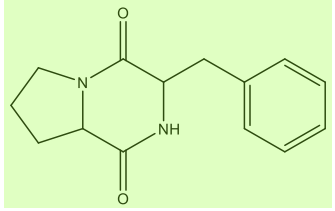
(125) 7-Hydroxy-1-(4-hydroxy-3-methoxyphenyl)-N2, N3-bis(4-hydroxyphenethyl)-6-methoxy-1,2-dihydronaphthalene-2,3-dicarboxamide 20

21

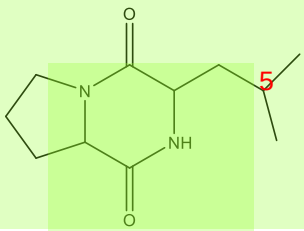


(126) Trans-4-hydroxy prolinebtaine 22

23



(127) Pyrrolo[1,2-A] Pyrazin-1,4-dione, hexahydro-3-(phenylmethyl) 24

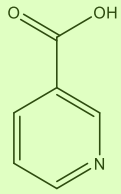


1

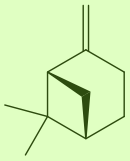
5

(128) Pyrrolo[1,2-A] Pyrazin-1,4-dione, hexahydro -3-(2-methylpropyl)

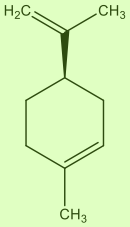
3



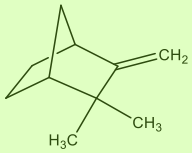
(131) Nicotinic acid



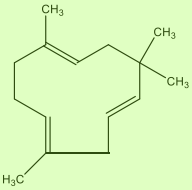
(134) 2-β-Pinene



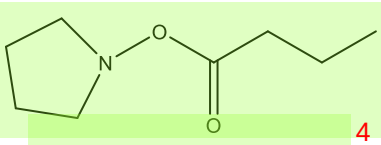
(137) Limonene



(140) Camphene

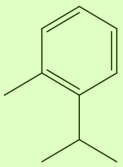


(143) α- Humulene

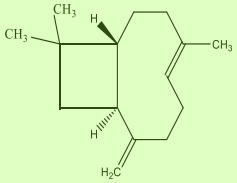


4

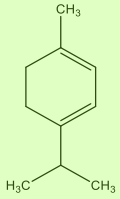
(129) Butanoic acid, pyrolidide



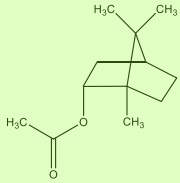
(132) *O*- cymene



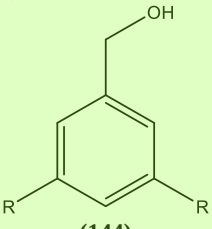
(135) Trans-Caryophyllene



(138) α-Terpinene



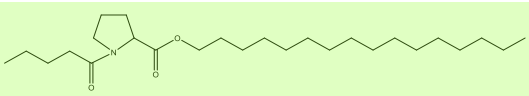
(141) Bornylacetate



(144)

6

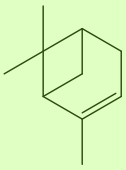
4-(hydroxymethyl) phenol	R = H
4-(hydroxymethyl)-2, 6 dimethoxyphenol	R =OCH_3



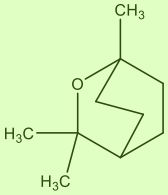
2

7

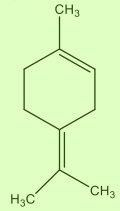
(130) L-proline, N-Valeryl-, hexadecyl ester



(133) α-Pinene

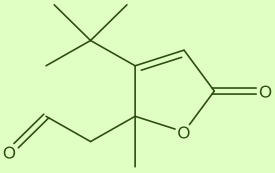


(136) 1, 8- Cineole

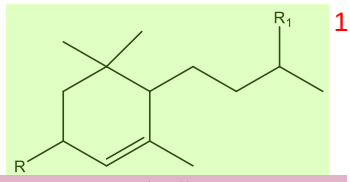


(139) α-Terpinolene

(142) Tridecane



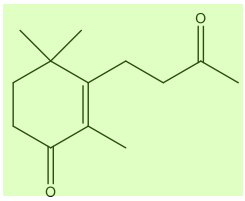
(145) Dehydrololiolide



1

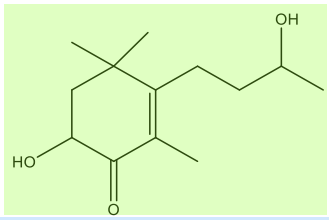
(146)
(9R)-9-hyroxymegastigm-4-ene-3-one
R=OR1=H, α OH
Megastigm-4-ene-3,9-dione
R=R1=O

2



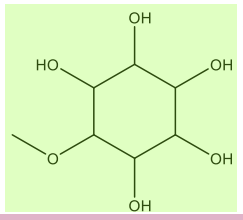
11

(147) 4-oxo-7, 8-dihydro-β-ionone 12



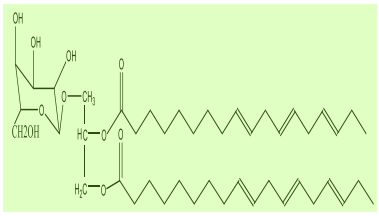
21

(148) (3R, 9R)-3,9-dihyroxymegastigm-5-en-4-one 22



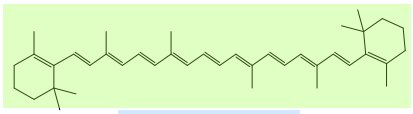
3

(149) 3-*O*-methyl-chiro-inositol 4



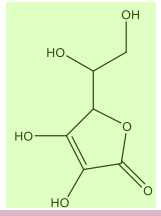
13

(150) Monogalactosyldiacylglycerol 14



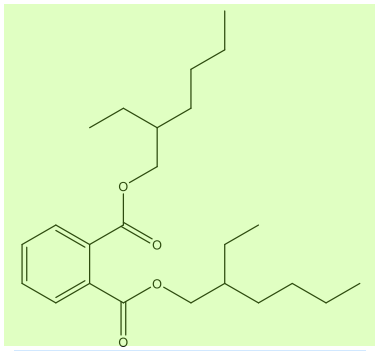
23

(151) β-Carotene 26



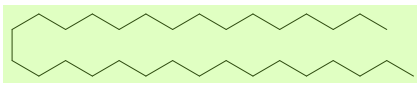
5

(152) Ascorbic acid 6



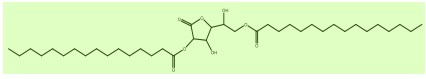
15

(153) Bis (2-ethyl hexyl) phthalate 16



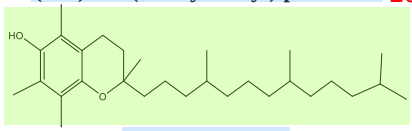
24

(154) Hentriacontane 25



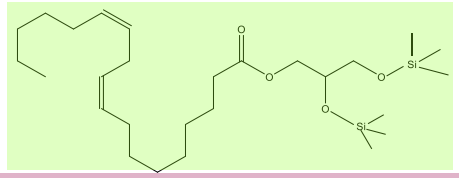
7

(155) L-(+)-ascorbic acid, 2-6-dihexaecanoate 8



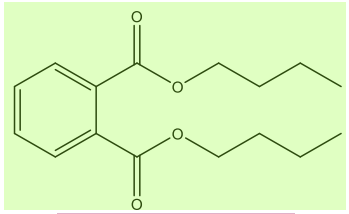
17

(156) Vitamin E 18



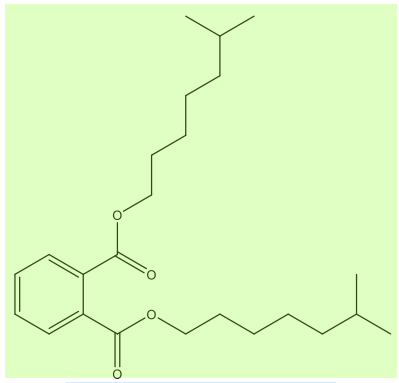
27

(157) 1-monolinoleoylglyceroltrimethylsilyl ether 28



9

(158) Dibutylphthalate 10



19

(159) Diisooctyl phthalate 20

Structures of isolated metabolites from family Aizozceae 29

T. decandra and *Sceletium spp.* was evaluated against formaldehyde-induced arthritis in rats, and a significant inhibition of chemically-induced arthritis, indicates anti-inflammatory potential[17-22-24-51].

Anti-inflammatory activity was evaluated in acute and chronic models. Significant anti-inflammatory activity was observed for chloroform extract of *T. decandra* in both carrageenan, dextran, and mediators induced edema models. The chloroform extract showed maximum inhibition of 58.36% at the dose of 200 mg/kg after 3 hrs of drug treatment in carrageenan-induced paw edema. The chloroform extract of *T. decandra* also exhibited significant anti-inflammatory properties in dextran-induced paw edema model. Dextran-induced paw edema is known to be mediated both by histamine and serotonin. Dextran induces fluid accumulation, which contains little protein and few neutrophils, whereas carrageenan induces protein rich exudation containing large number of neutrophils. The extract effectively suppressed the inflammation produced by both carrageenan and dextran[22].

Antimicrobial activity

It has been reported that the methanolic extract of *M. nodiflorum*, *M. crystallinum*, *M. forsskaolii*, and *Aizon canariense* showed a broad-spectrum antibacterial and antifungal activity against: *Bacillus subtilis*, *K. pneumonia*, *S. aureus*, *S. pyogenes*, *E. coli*, *A. fumigatus*, *A. nigar*, *C. albicans*, and *Mucor spp*[48].
For *C. edulis* five bioactive flavonoid compounds, rutin, neohesperidin, hyperoside, cactichin, and ferulic acid were isolated from the ethyl acetate fraction and individually or collectively were responsible for the antibacterial against 11 known human pathogenic bacteria, five Gram-positive: *Staphylococcus epidermidis*, *Staphylococcus aureus*, *Bacillus subtilis*, *Streptococcus pneumoniae*, *Streptococcus pyogenes*, and six Gram-negative: *Pseudomonas aeruginosa*, *Haemophilus influenzae*, *Eschericha coli*, *Klebsiella pneumoniae*, *Acinetobacter baumanii*, *Moraxella catarrhalis* [34]. Moreover, the isolated compounds from the ethanolic extract of *Galenia Africana* showed a remarkable antimycobacterial activity against *M. smegmatis* and *M. tuberculosis*[55].

The extracts and the essential oil from the fresh leaves of *S. portulacastrum* showed antibacterial, antifungal. The ethanolic extract showed potential antibacterial activity against the causative agents and pathogens related to various gastrointestinal disorders leading to indigestion, dysentery, and diarrhea[15]. Moreover, the ethanolic extract of the *S. portulacastrum* showed potential against the causative agents of nosocomial infections, *Staphylococcus aureus* and *E. coli*, while the essential oil exhibited notable antibacterial activity against both Gram-positive and Gram-negative bacteria as well as significant antifungal[15]. In addition, *S. portulacastrum*, showed positive activity against human immunodeficiency viruses[15]. Finally, it was reported that the new isolated flavonoid 2 - (3', 4' dihydroxy-phenyl) - 3, 5, 7-trihydroxy-chromen-4-one isolated from *T. decandra* showed antibacterial activity against *Pseudomonas aeruginosa* and by molecular docking it was found that FAS II β-hydroxyacyl-ACP (*FabZ)* of *P. aeruginosa* is a potential target of the isolated compound[40]. There are many other reported biological activities of members of family Aizoaceae as shown in **Table 11.**

CONCLUSIONS

From this review, it can be deduced that the major compounds of family Aizoaceae are alkaloids, triterpenes, flavonoids, sterols, lignans, fatty acids, phenolic acids, and essential oils. The review also showed that different extracts of aerial parts of plants of family Aizoaceae posse diverse biological activities such as anti-acetylcholinesterase, anti-butyrylcholinesterase, anti-infective, anti-hyperlipidemic, antipyretic, antifertility, diuretic, nephroprotective and others. It would, therefore, be important to extensively investigate their phytochemicals and pharmacologically determine their activities for future drug discovery and development.

Conflict of interest

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

REFERENCES

1. James, A.R. Mesembryanthemaceae, *Newsletter of the Tucson Cactus and Botanical Society*. **1982**, *12*, 1.
2. Rasingam, L. Aizoaceae (Magnoliopsida: Caryophyllales) - a new family record to the flora of Andaman Islands, India, *JOTT*. **2012**, *4* (6), 2653-2655.
3. Chesselet, P.; Mössmer, M.; Smith, G. Research priorities in the succulent plant family Mesembryanthemaceae Fenzl, *S. Afr. J. Sci.* **1995**, *91*, 197-209.
4. Bittrich, V.; Harbnann, E. The Aizoaceae - a new approach. *Bot. J. Linn. Soc.* **1988**, *97*, 239-254.
5. Eggli, U.; Hartmann, K. Illustrated Handbook of succulent plants, Springer-Verlag Berlin Heidelberg GmbH. **2001**, pp. 1-2.
6. Boulos L. Flora of Egypt. AzollaceaeOxalidaceae, Cairo, Egypt: Al-Hadara Publishing, **1999**.
7. Hosny A. Aizoaceae. In: El Hadidi MN, editor. Flora Aegyptiaca. The Palm Press., Cairo I, **2000**, 96-100.

8. Boulos L. Flora of Egypt, checklist. Al-Hadara Publishing, **1999**.
9. Hartmann H. Aizoaceae. In: Kubitzki K, Rohwer JG, Bittrich V, editors. the families and genera of vascular plants. II. Flowering Plants. Dicotyledons: Magnoliid, Hamamelid and Caryophyllid families. Berlin: Springer, **1993**, 37-69.
10. Vivrette, J.; Bleck, E.; Ferren, R. Aizoaceae Flora of North America, ed. N. R. Morin. New York, Oxford: Oxford University Press. **2003**, *4*, 75-91.
11. Heywood, H. Flowering plants of the world. Mayflower Books. Elsevier, New York, **2007**.
12. Walters, M.; Figueiredo, E.; Crouch, R.; Winter, D.; Smith, F.; Zimmermann, G.; Mashop, K. Aizoaceae, Council for Scientific and Industrial Research, South Africa. **2012**, 64-69.
13. Rood, B. Uit die veldapteek. Tafelberg Publishers, Cape Town,**1994**.
14. Elmarie, W.; Johan, C. Pretorius. Purification and identification of active antibacterial components in *Carpobrotus edulis* L. *J. Ethnopharmacol*. **2001**, *76*, 87–91.
15. Manbir, K.; Nitika. Review on Sea purslane, *J Pharmacogn Phytochem*. **2015**, *3*(5), 22-24.
16. Martins, A.; Vasas, A.; Schelz, S.; Viveiros, M., Molnar, J.; Hohmann, J.; Amaral, L. Constituents of *Carpobrotus edulis* Inhibit P Glycoprotein of *MDR1*-transfected Mouse Lymphoma Cells, *Anticancer Res*. **2010**, *30*(3), 829-836.
17. Gerickea, N.; Viljoenb, M. *Sceletium*— A review update, *J. Ethnopharmacol*. **2008**, *119*(3), 653–663.
18. Vealea, C.; Chenc, W.; Chaudharyc, S.; Kituyid, S.; Isaacsb, M.; Hoppe, H.; Edkins, A.; Combrinck, S.; Meharic, B.; Viljoenc, A. NMR structural elucidation of channaine, an unusual alkaloid from *Sceletium tortuosum*, *Phytochem. Lett.* **2018**, *23*, 189-193.
19. John, K. Mesembrine Alkaloids: Review of their Occurrence, Chemistry, and Pharmacology, *J. Ethnopharmacol*. **2017**, *195*, 10-19.
20. Jeffs, W.; Capps, M.; Redfearn, R. *Sceletium* alkaloids. Structures of five new bases from Sceletium namaquense. *J. Org. Chem.* **1982**, *47*, 3611–3617.
21. Cybulska, I.; Brudecki, G.; Alassali, A.; Thomsen, J. Phytochemical composition of some common coastal halophytes of the United Arab Emirates, *EJFA*. **2014**, *26*(12), 1046-1056.
22. Geethalakshmi, R., Sarada, L.; Ramasamy, K. *Trianthema decandra* L: A review on its phytochemical and pharmacological profile, *Int. J. Eng. Sci. Technol*. **2010**, *2*(5), 976-979.
23. Sukalingam, K.; Ganesan, K.; Ponnusamy, K.; Venugopal, V. Pharmacological Properties of *Trianthema portulacastrum* L and its Therapeutic Potential as Complementary Medicine, *JPCBS*. **2015**, *4* (2), 269-274.
24. Yamaki, J.; Kalyan C.; Venkata, N.; Mandal, A.; Bhattacharyya, P.; Bishayee, A. Health-promoting and disease-preventive potential of *Trianthema portulacastrum* Linn. (Gadabani) —An Indian medicinal and dietary plant, *J. Integr. Med*. **2016**, *14* (2), 84-99.
25. Al-Azzawi A.; Alguboori, A.; Hachim, Y., Najat M.; Al Shaimaa, A.; Sad, M. Preliminary phytochemical and antibacterial screening of *Sesuvium portulacastrum* in the United Arab Emirates, *Pharmacogn. Res*. **2012**, *4* (4), 219-224.
26. Sheela, D.; Uthayakumari, F. GC-MS analysis of bioactive constituents from coastal sand dune taxon *Sesuvium portulacastrum* (L.), *Bio. Disc.* **2013**, *4*(1), 47-53.
27. Geethalakshmi, R.; Sarada, L. In vitro and in silico antimicrobial activity of sterol and flavonoid isolated from *Trianthema decandra* L. *Microb. pathog*. **2018**, *121*, 77-86.
28. Afzal, S.; Chaudhary, B.; Uzair, M.; Afzal, K.; Bokhari, T. Isolation of pentandraone from methanolic extract of aerial parts of *Zaleya pentandra*, *Int. Res. J. Pharm*. **2013**, *4* (10), 21-23.
29. DellaGreca, M.; Fiorentinob, A.; Izzob, A.; Napolia, F.; Purcaroa, R.; Zarrellia, A. Phytotoxicity of Secondary Metabolites from *Aptenia cordifolia*, *Chem. Biodivers.* **2007**, *4*, 118-128.
30. DellaGreca, M.; Marino, C.; Previtera, L.; Purcaro, R.; Zarrelli, A. Apteniols A–F, oxyneolignans from the leaves of *Aptenia cordifolia*. *Tetrahedron*. **2005**, *61*, 11924-11929.
31. DellaGreca, M.; Previtera, L.; Purcaro, R.; Zarrelli, A. Cinnamic acid amides and lignanamides from *Aptenia cordifolia*. *Tetrahedron*. **2006**, *62*, 2877-2882.
32. Chandrasekaran, M.; Senthilkumar, A.; Venkatesalu, V. Antibacterial and antifungal efficacy of fatty acid methyl esters from the leaves of *Sesuvium portulacastrum* L., *Eur. Rev. Med. Pharmacol. Sci*. **2011**, *15*, 775-780.
33. Kumar, A.; Kumari, S.; Somasundaram, T. Gas Chromatography-Mass Spectrum (GC-MS) Analysis of Bioactive Components of the Methanol Extract of Halophyte, *Sesuvium portulacastrum* L., *IJAPB*. **2014**, *3* (3), 766-772.
34. Van der Watt, E.; Pretorius, C. Purification and identification of active antibacterial components in *Carpobrotus edulis* L., *J. Ethnopharmacol*. **2001**, *76*, 87–91.
35. Ibtissem, B.; Abdelly, C.; Sfar, S. Antioxidant and Antibacterial Properties of *Mesembryanthemum crystallinum* and *Carpobrotus edulis* Extracts, *ACES*. **2012**, *2*, 359-365.

36. Ibtissem, B.; Imen, M.; Souad, S. Dosage of 2, 6-Bis (1.1-Dimethylethyl)-4-Methylphenol (BHT) in the Plant Extract *Mesembryanthemum crystallinum*, *J Biomed Biotechnol.* **2010**, *2010*, 1-5.
37. Moawad, A.; Amin, E.; Mohammed, R. Diffusion-ordered Spectroscopy of Flavonol Mixture from *Mesembryanthemum forsskaolii* (Aizoaceae), *EJMP*. **2016**, *16*(1), 1-8.
38. Kavitha, D.; Parvatham, R.; Padma, R. Assessment of *trianthema portulacastrum* for its antimicrobial potential and investigation of their phytochemicals using HPTLC, GC-MS, and IR, *Int J Pharm Pharm Sci.* **2014**, *6* (1), 675-686.
39. Karim, M.; Kalam, A.; Alam, A.; Alam K.; Jahan, N.; Jafri, A. Biskhapra (*Trianthema portulacastrum Linn*) and its medicinal utility mentioned in Unani System of Medicine–A Review, *IJPSR*. **2015**, *6*(4), 790-795.
40. Geethalakshmi, R.; Sundaramurthi, J.; Sarada, L. Antibacterial activity of flavonoid isolated from Trianthema decandra against Pseudomonas aeruginosa and molecular docking study of FabZ. *Microb. Pathog*. **2018**, *121*, 87-92.
41. Impellizzeri, G.; Piattelli, M.; Sciuto, S. Acylated betacyanins from *Drosanthemum floribundum*, *Phytochemistry*. **1973**, *12*, 2295-2296.
42. Impellizzeri, G.; Piattelli, M.; Sciuto, S. A New betaxanthin from *glottiphyllum longum*, *Phytochemistry*. **1973**, *12*, 2293-2294.
43. Piattelli, M. Impellizzeri, G. Betacyanins from *lampranthus* sp. (aizoaceae), *Phytochemistry*. **1969**, *8*, 1595-1596.
44. Strack, D.; Bokern, M.; Marxen, N.; Wray, V. Feruloylbetanin from petals of *Lampranthus* and feruloylamaranthin from cell suspension cultures of *Chenopodium rubrum*, *Phytochemistry*. **1988**, *27*(11), 3529-3531.
45. Magwa, L.; Gundidza, M.; Gwerua, N.; Humphrey, G. Chemical composition and biological activities of essential oil from the leaves of *Sesuvium portulacastrum*, *J. Ethnopharmacol*. **2005**, *103*, 85–89.
46. Veeresh; Kumar, P.; Lavanya, A.; Suresh, P.; Mounika, N. Pharmacological potentials of *Trianthema decandra*- A review, *J Pharmacogn Phytochem.* **2017**, *6*(2), 290-294.
47. Gagare, B.; Jadhav, S. Comparative Phytochemical profiling of various extracts, from different parts of *Sesuvium portulacastrum* using GCMS, FTIR and ICP AES, *IJESM*. **2017**, *6*(6), 267-276.
48. El-Amier, A.; Haroun, A.; El-Shehaby, O.; Al-hadithy, N. Antioxidant and Antimicrobial Properties of Some Wild Aizoaceae Species Growing in Egyptian Desert, *J. Environ. Sci.* **2016**, *5* (1), 1-10.
49. Doudach, L.; Meddah, B.; Benbacer, L.; Hammani, K.; El mzibri, M.; Elomri, A.; Cherrah, Y. *Ethnopharmacological studies of Mesembryanthemum nodiflorum*, *Pharmacology*. **2013**, *4*(2), 246-258.
50. Mohammed, R.; El-Hawary, S.; Abo-youssef, M. Biological investigation of some wild *Aizoaceae* and *Chenopediaceae* species growing in Egypt, *J. Nat. Prod*. **2012**, *5*, 193-206.
51. Qasem, R. Prospects of wild medicinal and industrial plants of saline habitats in the Jordan valley, *Pak. J. Bot*. **2015**, *47* (2), 551-570.
52. Abdallah, A.; Ali Merito, A.; Hassan, S.; Aboubaker, D.; Djama, M.; Asfaw, Z.; Kelbessa, E. Medicinal plants and their uses by the people in the Region of Randa, Djibouti, *J. Ethnopharmacol*. **2013**, *148*, 701–713.
53. Stark, D.; Mtui, J.; Balemba, B. Ethnopharmacological survey of plants used in the traditional treatment of gastrointestinal pain, inflammation and diarrhea in Africa: future perspectives for integration into modern medicine. *Animals* **2013**, *3*, 158-227.
54. Omoruyi, E.; Bradley, G.; Afolayan, J. Antioxidant and phytochemical properties of *Carpobrotus edulis* (L.) bolus leaf used for the management of common infections in HIV/AIDS patients in Eastern Cape Province, *BMC Complem ALtern M*. **2012**, *12*, 215.
55. Van Wyk, E.; Van Oudtshoorn, B.; Gericke, N. Medicinal Plants of South Africa. *Briza Publications*, Pretoria, ISBN 1-875093-09-5, **1997**.
56. De Ghosh, M.; Ramakrishna, S.; Ramakrishna, M. Antimicrobial activity and phytochemical analysis of medicinal plants, *WJPPS*. **2014**, *3*(6), 1794-1799.
57. Moyo, B.; Mukanganyama, S. The Anticandidal and Toxicity Properties of *Lampranthus francisci*, *J. Mycol*. **2015**, *2015*, 1-15.
58. Van Wyk, E.; Gericke, N. People's Plants: A Guide to Useful Plants of Southern Africa, *Briza Publications*, Pretoria, ISBN 978-1-875093-s19-9, **2000**.
59. VanWyk, E. A broad review of commercially important southern African medicinal plants, *J. Ethnopharmacol*. **2008**, *119*, 342–355.
60. Afzal, S.; Chaudhary, B.; Ahmad, A.; Afzal, K. Preliminary phytochemical analysis and antifungal activities of crude extracts of *Zaleya pentandra* and *Corchorus depressus* linn., *Acta Pol Pharm*. **2015**, *72*, 329-334.
61. Afzal, S.; Chaudhry, B.; Afzal, K.; Saeed, J.; Hakash, S.; Qadir, M. Acetyl cholinesterase and butyryl cholinesterase inhibitory activities of *Zaleya pentandra*. *Acta Pol Pharm*. **2017**, *74* (3), 891-894.