Review

Biological Activities of Some New Secondary Metabolites Isolated from Endophytic Fungi: A Review Study

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Abstract: Secondary metabolites isolated from plant endophytic fungi have been getting more and more attention. Some secondary metabolites exhibit high biological activities, hence, they have potential to be used for promising lead compounds in drug discovery. In this review, a total of 134 journal articles (from 2017 to 2019) were reviewed and the chemical structures of 449 new metabolites, including polyketides, terpenoids, steroids and so on, were summarized. Besides, various biological activities and structure-activity relationship of some compounds were also described.

Keywords: new secondary metabolites; endophytic fungi; structural feature; biological activity

1. Introduction

During the growth of microorganisms, some secondary metabolites biologically active are produced to make their lives better. Using chemical and biological methods, Elshafie et al. displayed that the cell-free culture filtrate of Burkholderia gladioli pv. agaricicola (Bga) Yabuuchi has a promising antibacterial activity against the two microorganisms B. megaterium and E. coli [1]. Camele et al. reported that the tested isolate of an endophytic bacterium Bacillus mojavensis showed antagonistic bacterial and fungal activities against several strains as well as biofilm formation ability [2]. Endophytes refer to the microorganisms that exist in various organs, tissues or intercellular space of plants, while the host plants generally do not show any symptoms of infection. Generally speaking, endophytes include endophytic fungi, endophytic bacterium and endophytic actinomycetes [3]. As a very important microbial resource, endophytes exist widely in nature. It is ubiquitous in various terrestrial and aquatic plants. Endophytes have been isolated from bryophytes, ferns, pteridophytes, hornworts, herbaceous plants and various woody plants. The region also ranges from tropical to arctic, from natural wild to agricultural industry ecosystem [4]. They have unique physiological and metabolic mechanisms, which enable them to adapt to the special environment inside plants, and at the same time, they can encode a variety of bioactive substances. In addition, endophytes coevolved with the host plants for a long time to produce some metabolic substances similar or identical to the host plants with medicinal value [5]. Some endophytes can even assist the host of medicinal plants to synthesize effective active compounds, the ground-breaking discovery provides a new method to produce the effective compounds which have similar effects with natural medicines isolated from plant tissues directly. At the same time, it has solved the problem of resource shortage and ecological destruction caused by slow growth of some natural plants and large amount of artificial exploitation [3]. The more beneficial thing is that some of them are environmentally friendly. Elshafie et al. have studied the fungus Trichoderma harzianum strain T22 (Th-T22) and indicated that Th-T22 showed significant mycoremediation ability in diesel-contaminated sand, suggesting that it can be used as a bioremediation agent for diesel spills in polluted sites [6]. Among the common endophytes, the endophytic fungi are most often isolated [4]. The first endophytic fungus was isolated from Perennial
ryegrass (*Lolium tatum eletum*) seeds by Vogle in 1898 [7]. Up to now, the study on endophytic fungi has a long history of more than 100 years, but the research on endophytic fungi of medicinal plants has not been formally carried out until the last 30 years, which has gradually attracted the attention of domestic and foreign scholars.

The multiformity of endophytes enable they can produce a variety of secondary metabolites. In recent years, the metabolites isolated from the endophytic fungi include alkaloids, steroids, terpenes, anthraquinones, cyclic peptides, flavonoids commonly [5]. Some secondary metabolites exhibit high biological activities. The antitumor, antibacterial, anti-inflammatory, antiviral, antifungal and other compounds have been produced by different endophytic fungi. Therefore, the chemical variety of secondary metabolites produced by endophytic fungi has advantage for new drug development [8].

In this review, 449 new secondary metabolites, together with their chemical structures and biological activities were summarized. The structure-activity relationships and absolute configuration of some compounds have also been described. Among all new compounds, terpenoids account for the largest proportion (75%), followed by polyketones (36%). The proportion of different types of compounds in all new compounds is shown in Figure 1. These new compounds were isolated from various fungi associated with different tissues from different plants. As a result, their structures varied a lot, which leads to their multitudinous biological activities. In addition to common antimicrobial activity and anti-tumor activity, some compounds also showed anti-enzyme activity and inhibition of biofilm formation, inhibition of phytoplankton growth, and so on.

![The percentage of various compounds](image)

**Figure 1.** Percentage of metabolites synthesized by endophytes.
2. New Metabolites Isolated from Plant Endophytes

2.1. Terpenoids

2.1.1. Sesquiterpenoids and Their Derivatives

Five new polyketide-terpene hybrid metabolites 1–5 (Figure 2) with highly functionalized groups, were isolated from the endolichenic fungus Pestalotiopsis sp. [9]. Co-cultivation of mangrove endophytic fungus Trichoderma sp. 307 and aquatic pathogenic bacterium Acinetobacter johnsonii B2 led to the production of two new furan-type isorhizinoline sesquiterpenes, microphaeropsins B 6 and microphaeropsisin C 7 (Figure 2). Their absolute configuration were assigned as 4S, 5R, 7R, 8S, 11S and 4R, 5R, 7R, 8S [10]. Following cultivation on rice medium, a new sesquiterpene, atrichodermone C 8 (Figure 2), was isolated from an endophytic fungal strain named Trichoderma atroviride which was isolated from the bulb of Lycoris radiate [11]. There is an endophytic fungus Pestalotiopsis sp. which was obtained from fruits of Drepanocarpus lunatus (Fabaceae). Co-culture of this fungus with Bacillus subtilis afforded two new sesquiterpenoids pestabacillins A 9 (Figure 2) and pestabacillins B 10 (Figure 2) [12]. Two new sesquiterpene-epoxycyclohexenone conjugates, nectrianolins A 11 (Figure 2) and nectrianolins B 12 (Figure 2), together with a sesquiterpene, nectrianolin C 13 (Figure 2), were isolated from the brown rice culture of Nectria pseudotrichia 120-1NP, an endophytic fungus isolated from Gliricidia sepium. It is of particular interest that 11 and 12 have a rearranged monocyclofarnesyl skeleton (which is uncommon to sesquiterpene-epoxycyclohexane conjugates) instead of a bicyclofarnesyl skeleton which is present in macrophorins, neomacrophorins, myrothecols, and craterellins [13]. It was found that endophytic Nigrospora oryzae stimulated the production of a new tremulane sesquiterpene nigrosirpexin A 14 (Figure 2) from Irpex lacteus [14]. Two novel sesquiterpenoids with an unprecedented tricyclo[4,4,2,1]hendecane scaffold, namely emericellins A 15 (Figure 2) and emericellins B 16 (Figure 2) representing a new skeleton, were isolated from the liquid cultures of an endophytic fungus Emericella sp. XL 029 associated with the leaves of Panax notoginseng [15]. Two trichothecene sesquiterpenoids, trichothecocins A 17 (Figure 2) and trichothecrolsins B 18 (Figure 2), and a pair of meso- sesquiterpenoid racemates, (+)-trichothecocin C 19 (Figure 2) and (−)-trichothecocin C 20 (Figure 2), were obtained from potato endophytic fungus Trichothecium crotocinigenum by bioguided isolation. Compounds 17 and 18 are trichothecenes possessing new ring systems. Compounds 19 and 20 possess novel 6/6/5/6 fused ring system [16]. Chemical investigation on the solid rice culture of Trichoderma atroviride S361, an endophyte isolated from Cephalotaxus fortunei, has afforded a new cyclohexeneone sesquiterpenoid, trichodermadione B 21 (Figure 2) [17]. Seven new phenolic bisabolane sesquiterpenoids, (7R,10S)-7,10-epoxysydonic acid 22 (Figure 2), (7S,10S)-7,10-epoxysydonic acid 23 (Figure 2), (7R,11S)-7,12-epoxysydonic acid 24 (Figure 2), (7S,11S)-7,12-epoxysydonic acid 25 (Figure 2), 7-deoxy-7,14-didehydro-12-hydroxysydonic acid 26 (Figure 2), (Z)-7-deoxy-7,8-didehydro-12-hydroxysydonic acid 27 (Figure 2), and (E)-7-deoxy-7,8-didehydro-12-hydroxysydonic acid 28 (Figure 2), were obtained from the culture of an endophytic fungus Aspergillus sp. xy02 isolated from the leaves of a Thai mangrove Xylocarpus moluccensis [18]. Pestalustaines A 29 (Figure 2), one unique sesquiterpene possessing an unusual 5/6/5 fused ring system was isolated from the plant-derived Pestalotiopsis adusta [19]. A new acorane sesquiterpene, 3β-hydroxy-β-acoranol 30 (Figure 2), possesses an acorane framework was separated from the extract of the green Chinese onion derived fungus Fusarium proliferatum AF-04 [20]. An examination of the endophytic fungus Trichoderma asperellum A-YMD-9-2 obtained from the marine red alga Gracilaria verrucosa led to the isolation of seven new chromanoid norbisabolane derivatives, trichobisabolins I–L 31–34 (Figure 2) and trichaspsides C–E 35–37 (Figure 2). The discovery of compounds 31–37 greatly diversifies the structures of norbisabolane sesquiterpenes [21]. Oxytropiols A–J 38–47 (Figure 2), ten undescribed highly oxygenated guaiane-type sesquiterpenoids, were isolated from the locoweed endophytic fungus Alternaria oxytropis [22]. Studies on the bioactive extract of mangrove endophytic fungus Pleosporales sp. SK7 led to the isolation of an abscisic acid-type sesquiterpene 48 (Figure 2), named (10S, 2Z)-3-methyl-5-(2,6,6-trimethyl-4-oxocyclohex-2-
enyl)pent-2-enoic acid [23]. One new tremulane sesquiterpene, irpexlacte A 49 (Figure 2), was isolated from the endophytic fungus *Irpex lacteus* DR10-1 waterlogging tolerant plant *Distylium chinense* [24]. Trichocadins B–G 50–55 (Figure 2), six new cadinane-type sesquiterpene derivatives, each with C-14 carboxyl functionality, were isolated from the culture extract of *Trichoderma virens* QA-8, an endophytic fungus obtained from the fresh inner tissue of the medicinal plant *Artemisia argyi* [25]. Chemical investigation of the EtOAc extract of the plant-associated fungus *Alternaria alternate* in rice culture led to the isolation of a new sesquiterpene (1R,5R,6R,7R,10S)-1,6-Dihydroxyeudesm-4(15)-ene 56 (Figure 2) [26]. An investigation of a co-culture of the *Armillaria* sp. and endophytic fungus *Epicoccum* sp. YUD17002 associated with *Gastrodia elata* led to the isolation of five protoilludane-type sesquiterpenes named epicoterpenes A–E 57–61 (Figure 2). Compound 60 was the first example of an ent-protoilludane sesquiterpenoid scaffold bearing a five-membered lactone. Notably, none of the new compounds were produced by either of the two fungi when cultured alone under the same conditions [27]. A new sesquiterpene lactone, namely colletotrin 62 (Figure 2), was obtained from a rice culture of *Colletotrichum gloeosporioides*, an endophytic fungus isolated from the stem bark of Cameroonian medicinal plant *Trichilia monadelpha* (Meliaceae) [28]. Purpurolide A 63 (Figure 2), an unprecedented sesquiterpene lactone with a rarely encountered 5/5/5 spirocyclic skeleton, along with two new 6/4/5/5 tetracyclic sesquiterpene lactones purpurolide B and C 64–65 (Figure 2), were isolated from the cultures of the endophytic fungus *Penicillium purpurogenum* IMM003 [29]. Bioassay-guided fractionation of the crude extract of fermentation broth of one symbiotic strain *Fusarium oxysporum* ZZP-R1 derived from coastal plant *Rumex madaio* Makino, one traditional Chinese medicine used as a treatment of inflammation and toxication, yielded one novel compound, fusarumins D 66 (Figure 2). Chemical structure of 66 was determined as a sesquiterpene ester with a conjugated triene and an unusual oxetene ring by a combination of spectroscopic methods [30].

Figure 2. Cont.
Figure 2. Cont.
2.1.2. Diterpenoids

One new cleistanthene-type diterpene zyliostromic acid C 67 (Figure 3), which structure was assigned as 3α,5α,7β,8β-tetrahydroxyclestanth-13(17),15-dien-18-oic acid, was isolated from the brown rice culture of Nectria pseudotrichia 120-1NP [31]. A fungal strain, Drechmeria sp., was isolated from the root of Panax notoginseng. Totally, seven new indole diterpenoids, drechmerins A–G 68–74 (Figure 3), were isolated from the fermentation broth of Drechmeria sp. [32]. A novel 1(2), 2(18)-diseco indole diterpenoid, drechmerin H 75 (Figure 3), was isolated from the fermentation broth of Drechmeria sp. together with a new indole diterpenoid, 2′-epi terpendole A 76 (Figure 3) [33]. An endophytic fungus, Neosartorya fischeri JS0553, was isolated from G. littoralis plant. From the fungus, a new meroditerpenoid named sartorypyrone E 77 (Figure 3) was isolated [34]. Two new oxoindolo diterpene epimers, anthcolorin G 78 (Figure 3) and anthcolorin H 79 (Figure 3), isolated for the first time from a natural source, were isolated from the solid rice culture of the endophytic fungus Aspergillus versicolor [35]. A new isopimarane derivative which was named as xylaroisopimaranin A 80 (Figure 3) and the absolute configurations was determined as 4S, 5R, 9R, 10R, 13R and 14S, was isolated from the plant endophytic fungus Xylaralyce sp. (HM-1) [36]. The endolicenic fungus Apiospora montagnei isolated from the lichen Cladonia sp. was cultured on solid rice medium, yielding a new diterpenoid libertellenone L 81 (Figure 3), compound 81 represented the first example of 6,7-seco-libertellenone derivative [37].
2.1.3. Other Terpenoids

Eleven new ophiobolin-type sesterterpenoids, asperophiobolins A–K 82–92 (Figure 4), were isolated from the cultures of the mangrove endophytic fungus Aspergillus sp. ZJ-68. Asperophiobolins A–D (82–85) represented the first examples possessing a five-membered lactam unit between C-5 and C-21 in ophiobolin derivatives. The absolute configuration of...
compounds were defined as (2S,3R,5S,6R,11R,14R,15S) (82–84), (2S,3R,5S,6R,10S,11R,14R,15S) (85), (2S,6S,10S,11R,14R,15S,18S) (87), (2S,6R,10S,11R,14R,15S,18S) (88), (2S,6S,10S,11R,14R,15S,18S) (89), (2S,6S,10S,11R,14R,15S,18S) (90), (2S,3R,6R,10S,11R,14R,15S,18S) (91), (2R,3R,5R,6R,10S,11R,14R,15S) (92) [38]. From Kadsura angustifolia fermented by an associated symbiotic endophytic fungus, Penicillium sp. SWUKD4.1850, nine undescribed triterpenoids, kadhenrischinins A–H 93–100 (Figure 4), and 7β-schinalactone C 101 (Figure 4) were isolated and established. All these metabolites have been first detected in non-fermented K. angustifolia. Structurally, kadhenrischinins A–D (93–96) belong to the relatively rare class of highly oxygenated schitriterpenoids that contain a unique 3-one-2-oxabicyc[3.2.1]-octane motif, while kadhenrischinins E–H (97–100) feature acyclopentane ring in a side chain rarely found in the family Schisandraceae [39]. Meroterpenoids with diverse ring systems including five new ones (102–106) (Figure 4), were isolated from Phyllosticta capitalensis, an endophytic fungus from Cephalotaxus fortunei Hook. Compound 103 represented a novel guignardone derivative possessing a 5/7/6/5 ring system with CH2-7 attached to C-4 rather than C-6 in ring D [40]. Nine new meroterpenes, (7R,8R)-8-hydroxy-sydowic acid 107 (Figure 4), (7S,10S)-10-hydroxy-sydowic acid 108 (Figure 4), (7S,11R)-12-hydroxy-sydowic acid 109 (Figure 4), (7S,11R)-12-acetoxy-sydowic acid 110 (Figure 4), (7R,8R)-1,8-epoxy-11-hydroxy-sydonic acid 111 (Figure 4), 7-deoxy-7,14-didehydro-11-hydroxy-sydonic acid 112 (Figure 4), 7-deoxy-7,14-didehydro-12-acetoxy-sydonic acid 113 (Figure 4), and (E)-7-deoxy-7,8-didehydro-12-acetoxy-sydonic acid 114 (Figure 4), (7R)-11-hydroxy-sydonic acid methyl ester 115 (Figure 4), were isolated from the solid rice culture of fermentation broth of one symbiotic strain Fusarium oxysporum ZZP-R1 derived from coastal plant Rumex madaio Makino, one traditional Chinese medicine used as a treatment of inflammation and toxication, yielded one novel compound, fusariurnins C 116 (Figure 4). Chemical structure of 116 was determined as one meroterpene with cyclohexanone moiety [30]. A new monoterpentoid lithocarin D 117, was isolated from the endophytic fungus Diaporthe lithocarpus A740 (Figure 4) [41].

Figure 4. Cont.
2.2. Keton Compounds

2.2.1. Polyketides

An endophytic fungus, *Eupenicillium* sp. LG41, isolated from the Chinese medicinal plant *Xanthium sibiricum*, was subjected to epigenetic modulation using an NAD+ dependent histone deacetylase (HDAC) inhibitor, nicotinamide. Epigenetic stimulation of the endophyte led to enhanced production of two new decalin-derived polyketides with a

Figure 4. Chemical structures of other terpenoids and derivatives.
2.2. ketone compounds

2.2.1. polyketides

An endophytic fungus, Eupenicillium sp. LG41, isolated from the Chinese medicinal plant Xanthium sibiricum, was subjected to epigenetic modulation using an NAD+-dependent histone deacetylase (HDAC) inhibitor, nicotinamide. Epigenetic stimulation of the endophyte led to enhanced production of two new decalin-derived polyketides with a double bond between C-3 and C-4, eucinnicinols C 118 (Figure 5) and D 119 (Figure 5) [42]. On the basis of One Strain/Many Compounds (OSMAC) strategy, five new polyketides, named phomosipketones A–C 120–122 (Figure 5), (10S)-10-O-b-D-40-methoxymannopyranosylidiothérin 123 (Figure 5), and clearanol 124 (Figure 5), were isolated from an endophytic fungus, Phomopsis sp. sh917, harbored in stems of Isodon ericoidaly var. laxiflora [43]. As naturally occurring polyketides, ten new salicylaldehyde derivatives, namely vacnolins J–S 125–134 (Figure 5), were isolated from Pestalotiopsis vaccinii (cgmcc3.9199) endogenous with the mangrove plant Kandelia candel (L.) Druce (Rhizophoraceae) [44]. Twelve new polyketides, penicichrosygenins A–L 135–146 (Figure 5), were isolated from the solid substrate fermentation cultures of a Huperzia serrata endophytic fungus Penicillium chrysogenum MT-12. The structures of 135–139 were established (2R)-6-hydroxy-2,4-dimethoxy-5-methylphthalide (135), 4,6-dihydroxy-5-hydroxymethylphthalide9 (136), 4,6-dihydroxy-5-methoxymethylphthalide (137), (2R)-4,5-dihydroxy-2,6-dimethoxy-2-pentylphthalide (138), (E)-4,5-dihydroxy-2-(4-hydroxypentyliden)-6-methoxyphthalide (139), respectively [45]. Three new polyketides, cylindrocarpens A–C 147–149 (Figure 5), were isolated from the endophytic fungus, Cylindrocarpon sp., obtained from the tropical plant Sapium ellipticum [46]. Six new xanthone-derived polyketides, named phomoxanthones F–K 150–155 (Figure 5), were isolated from Phomopsis sp. xy21, which was isolated as an endophytic fungus from the Thai mangrove Xylocarpus granatum. Phomoxanthone F 150 represented the first xanthone-derived polyketide containing a 10α-decarboxylated benzopyranone nucleus that was substituted by a 4-methylidihydrofuraran-2(3H)-one moiety at C10α. Phomoxanthones G 151 and H 152 are highly oxidized xanthone-derived polyketides containing a novel 5-methyl-6-oxabicyclo[3.2.1]octane motif [47]. Compound 156 (Figure 5), 5,9-dihydroxy-2,4,6,8,10-pentamethyldodeca-2,6,10-trienyl, a novel polyketide molecule was isolated from Aspergillus floculosus endophyte isolated from the medicinal plant Markhania platyclay [48]. Three new polyketides, (2S)-2,3-dihydro-5,6-dihydroxy-2-methyl-4H-1-benzopyran-4-one (Figure 5), (2R)-2-(2′-hydroxypropyl)-4-methoxyl-1,3-benzenediol 158 (Figure 5), and 4-ethyl-3-hydroxy-6-propenyl-2H-pyran-2-one 159 (Figure 5) were isolated from the culture broth of Colletotrichum gloeosporioides, an endophytic fungus derived from the mangrove Cerioa tagal [49]. Five polyketides, paralactonic acids A–E 160–164 (Figure 5) were isolated from Paraconiothyrium sp. SW-B-1, an endophytic fungus isolated from the seaweed, Chondrus ocellatus Holmes [50]. Four new polyketides, alternatans A–D 165–168 (Figure 5), were obtained from the solid substrate fermentation cultures ofAlternaria alternata MT-47, an endophytic fungus isolated from the medicinal plant Huperzia serrata [51]. From extracts of the plant associated fungus Chaetosphaeronema achilleae collected in Iran, two polyketides including a previously unreported isosindoline named chaetosindolinolone 169 (Figure 5) and a previously undescribed indanone named chaetosindanolone 170 (Figure 5) were isolated [52]. During a survey of the secondary metabolites of endophytic fungi Aspergillus porosus, new polyketides with interesting structural features named porosuphenols A–D 171–174 (Figure 5) were found [53]. Chemical investigation of the EtOAc extract of the plant-associated fungus Alternaria alternata in rice culture led to the isolation of a novel lipophilic polyketone, altermin A 175 (Figure 5), which possesses an unprecedented C25 lipophilic polyketone skeleton [26]. Five new polyketides, colletotric B 176 (Figure 5), 3-hydroxy-5-methoxy-2,4,6-trimethylbenzoic acid 177 (Figure 5), colletotric C 178 (Figure 5), chaetochrome D 179 (Figure 5) and 8-hydroxypregaliellalactone B 180 (Figure 5), were isolated from the mangrove endophytic fungus Phoma sp. SYSU-SK-7 [54]. The EtOAc extract of Phomopsis sp. D15a2a isolated from the plant Alternanthera bettzickiana following fermentation on solid rice medium yielded
three new polyketides, phomopones A–C 181–183 (Figure 5) [55]. Three new polyketides including two benzophenone derivatives, penibzones A (184) and B (185) (Figure 5), and a new phthalide derivative, penibenzone C 186 (Figure 5), were isolated from the solid-substrate cultures of the endophytic fungus *Penicillium purpurogenum* IMM003 [56].

Figure 5. Cont.
Figure 5. Chemical structures of polyketides.
2.2.2. Other Ketones

A new N-methoxypyridone analog 11S-hydroxy-14-methyl cordypyridone C 187 (Figure 6), was isolated from the co-culture of Hawaiian endophytic fungi Camporesia sambuci FT1061 and Epicoccum sorghinum FT1062 [57]. A novel endophyte Rhytismataceae sp. DAOMC 251461 produced two new dihydropyrones: (R)-4-hydroxy-5-octanoyl-6-oxo-3,6-dihydropyran-2-carboxylic acid (rhytismatone A) 188 (Figure 6) and (R)-methyl-4-hydroxy-5-octanoyl-6-oxo-3,6-dihydropyran-2-carboxylate (rhytismatone B) 189 (Figure 6) [58]. Five new bioactive 2-pyrone metabolites, phomaspyrones A–E 190–194 (Figure 6), were isolated from the culture broth of an endophytic fungus Phomopsis asparagi SWUKJ5.2020 of medicinal plant Kadsura angustifolia. The structures of 190–194 were identified as (S)-5-(1,2-dihydroxyethyl)-6-hydroxymethyl-4-methoxy-2H-pyran-2-one (190), (S)-5-(1-hydroxyethyl)-6-hydroxymethyl-4-methoxy-2H-pyran-2-one (191), (5S,8R)-5,8-dihydroxy-4-methoxy-5,6-dihydropyrano-[3,4-b]pyran-2(8H)-one (192), 4-methoxy-6-methyl-5-(2-oxobutyl)-2H-pyran-2-one (193), 6-(hydroxymethyl)-4-methoxy-5-(2-oxobutyl)-2H-pyran-2-one (194) respectively [59]. Extracts from an endophytic fungus Dendrothyrium variisporum isolated from the roots of the Algerian plant Globularia alypum produced two new minor furanone derivatives: methyl (5S)-5-[(10E,30Z)-hexa-1,3-dienyl]-5-methyl-4-oxo-2-methyl-4,5-dihydrofuran-3-carboxylate ((5S) cis-gregatin B) 195 (Figure 6), (5R)-5-[(10E,30Z)-hexa-1,3-dienyl]-5-methyl-4-oxo-2-(4S,1E)-4-hydroxypent-1-enyl)-4,5-dihydrofuran-3-carboxylate, (graminin D) 196 (Figure 6) [60]. Two new compounds isobenzofuranone A 197 (Figure 6) and indandione B 198 (Figure 6), were isolated from liquid cultures of an endophytic fungus Alternaria sp., which was obtained from the medicinal plant Morinda officinalis. Among them, the indandione 198 showed a rarely occurring indanone skeleton in natural products [61]. An endophytic fungal strain named Trichoderma atroviride was isolated from the bulb of Lycoris radiata. Following cultivation on rice medium, a new cyclopentenone derivative, atrichodermone B 199 (Figure 6), was isolated [11]. One previously undescribed isochromone derivative 6,8-dihydroxy-3-(2-hydroxypropyl)-7-methyl-1H-isochromen-1-one 200 (Figure 6), was isolated from the culture of the endophytic fungus Eurotium chevalieri KUFA 0006 [62]. One previously undescribed pyrone (simplicilopyrone) 201 (Figure 6) was isolated from the endophytic fungus Simplicillium sp. PSU-H41 [63]. Cytosporophenones A–C, one new polyhydric benzophenone 202 (Figure 6) and two new naphtopyrone derivatives 203–204 (Figure 6), were isolated from Cytospora rhizophorae, an endophytic fungus from Morinda officinalis [64]. A novel pyrone derivative 205 (Figure 6) bearing two fused five-member rings, together with two new naphthalenone derivatives 206–207 (Figure 6), were obtained from the endophytic fungus Fusarium sp. HP-2, which was isolated from the “Qi-Nan” agarwood [65]. Two new compounds penibenzophenones A-B 208–209 (Figure 6), were isolated from the EtOAc extract of the endophytic fungus Penicillium citrinum HL-5126 isolated from the mangrove Bruguiera sexangula var. rhynchopetala collected in the South China Sea [66]. Two new isochromanone derivatives, (3S,4S)-3,8-dihydroxy-6-methoxy-3,4,5-trimethylisochroman-1-one 210 (Figure 6) and methyl (S)-8-hydroxy-6-methoxy-5-methyl-4a-(3-oxobutan-2-yl)benzoate 211 (Figure 6), were isolated from the cultures of an endophytic fungus Phoma sp. PF2 obtained from Artemisia princeps [67]. Isoshamixanthone 212 (Figure 6), a new stereoisomeric pyrano xanthone was obtained from the endophytic fungal strain Aspergillus sp. ASCLA isolated from leaf tissues of the medicinal plant Callistemon subulatus [68]. From the endophytic fungus, Cylindrocarpus sp., obtained from the tropical plant Sapium ellipticum, a new pyrano cylindropyrene 213 (Figure 6) was isolated [46]. One new benzophenone derivative, named tenllone I 214 (Figure 6), was isolated from the endophytic fungus Diaporthe lithocarpus A740 [41].
2.3. Alkaloids and Their Derivatives

The endolichenic fungus *Apiospora montagnei* isolated from the lichen *Cladonia* sp. was cultured on solid rice medium, yielding a new pyridine alkaloid, 23-O-acetyl-N-hydroxyapiosporamide 215 (Figure 7) [37]. Chaetoindolin A 216 (Figure 7), a new indole alkaloid derivative was isolated from the endophytic fungus *Chaetomium globosum* CDW7 [69]. A synthetic α,β-unsaturated amide alkaloid (E)-tert-butyl(3-cinnamamidopropyl) carbamate 217 (Figure 7), newly identified as a natural product, was isolated from the EtOAc extract of the endophytic fungus *Penicillium citrinum* HL-5126 isolated from the mangrove *Bruguiera sexangula* var. *Rhynchopetala* [66]. A new alkaloid, 1, 2-dihydrophenopyrrozin 218 (Figure 7), was isolated from an axenic culture of the endophytic fungus, *Bionectria* sp., obtained from seeds of the tropical plant *Raphia taedigera* [70]. Two new pyridone alkaloids, cylindrocarpyridones A–B 219–220 (Figure 7), were isolated from the endophytic fungus, *Cylindrocarpon* sp., obtained from the tropical plant *Sapium ellipticum* [46]. From *Aspergillus versicolor*, an endophyte derived from leaves of the Egyptian water hyacinth *Eichhornia crassipes* (Pontederiaceae), one new compound aflaquinolone H 221 (Figure 7) belonging to dihydroquinolone alkaloids was obtained [71]. Two new spiroketal derivatives as alkaloids with an unprecedented amino group, 2′-aminodechloromaldoxin 222 (Figure 7) and 2′-aminodechlorogeodoxin 223 (Figure 7), were isolated from the plant endophytic fungus.
Pestalotiopsis flavidula [72]. The biotransformation of lycopodium alkaloid huperzine A (hupA), one of the characteristic bioactive constituents of the medicinal plant Huperzia serrata, by a fungal endophyte of the host plant was studied. Two previously undescribed compounds 224–225 (Figure 7), were isolated and identified [73]. Chemical investigation of the EtOAc extract of the plant-associated fungus Alternaria alternate in rice culture led to the isolation of a new indole alkaloid 226 (Figure 7) [26]. Bioactivity-guided isolation of the endophytic fungus Fusarium sambucinum TE-6L residing in Nicotiana tabacum L. led to the discovery of two new angularly prenylated indole alkaloids (PIAs) with pyrano[2,3-g]indole moieties, amoenamide C 227 (Figure 7) and sclerotiamide B 228 (Figure 7). Compound 227 containing the 8 bicyclo[2.2.2]diazaoctane core and indoxyl unit was rarely reported [74].

![Chemical structures of alkaloids and their derivatives.](image)

2.4. Penylpropanoids and Their Derivatives

A new isocoumarin (3R,4S,4aR,6R)-4,6,8-trihydroxy-3-methyl-3,4,4a,5,6,7-hexahydroisochromen-1-one 229 (Figure 8) was isolated from an endophyte Mycosphaerellaceae sp. DAOMC 250863 [58]. Using the bioassay-guided method, one new isocoumarin derivative, prochaetoviridin A 230 (Figure 8), was isolated from C. globosum CDW7, an endophyte from Ginkgo biloba [66]. A new isocoumarin derivative pestalotiopisorin B 231 (Figure 8), was isolated from Pestalotiopsis sp. HHL-101, an endophytic fungus obtained from Chinese mangrove plant Rhizophora stylosa [75]. In continuing search of fungal strain Nectria pseudotrichia 120-1NP, two new isocoumarins, namely, nectriapyriones A 232 (Figure 8) and B 233 (Figure 8) were identified [31]. Two new isocoumarin dimers 234–235 (Figure 8) were isolated from Aspergillus versicolor, an endophyte derived from leaves of the Egyptian water hyacinth Eichhornia crassipes (Pontederiaceae) [71]. Pestalustaines 236 (Figure 8), one unprecedented coumarin derivative bearing 6/6/5/5-fused tetracyclic ring system, was isolated from a plant-derived endophytic fungus Pestalotiopsis adusta [19]. Compounds 237 (Figure 8) and 238 (Figure 8), determined as two novel isocoumarin derivatives with a different butanetriol group at C-3, were produced by T. harzianum (Tricho-
Two pairs of new isocoumarin derivatives penicoffrazins B and C, 239–240 (Figure 8), were isolated from Penicillium coffeae MA-314, an endophytic fungus obtained from the fresh inner tissue of the leaf of marine mangrove plant Laguncularia racemosa [77]. A new dihydroisocoumarin, diaporone A 241 (Figure 8), was isolated from the ethyl acetate extract of the cultures of the endophytic fungus Diaporthe sp. [78].

From the seeds of the traditional medicinal plant Ziziphus jujuba growing in Uzbekistan, the fungal endophyte Alternaria sp. was isolated. Extracts of this fungus yielded a new natural phthalide derivative 7-methoxyphthalide-3-acetic acid 242 (Figure 9) [79]. Three new lactone Derivatives isoaigialones, A, B, and C 243–245 (Figure 9), were isolated from the crude EtOAc extract of a Phaeoacremonium sp., an endophytic fungus obtained from the leaves of Senna spectabilis. 245 is epimeric at C-7 relative to compound 244 [80]. A new phytotoxic bicyclic lactone (3aS,6aR)-4,5-dimethyl-3,3a,6,6a-tetrahydro-2H-cyclopenta[b]furan-2-one [81].

Three new lactones de-O-methyllasiodiplodins, (3R,7R)-7-hydroxy-de-O-methyllasiodiplodin 247 (Figure 9) and (3R)-5-oxo-deO-methyllasiodiplodin 248 (Figure 9), together with (3R)-7-oxo-de-O-methyllasiodiplodin 249 (Figure 9) were isolated from the co-cultivation of mangrove endophytic fungus Trichoderma sp. 307 and aquatic pathogenic bacterium Acinetobacter johnsonii B2 [10].

Two new lactones, pestalotiolactones A 250 (Figure 9) and B 251 (Figure 9), were isolated from the axenic culture of the endophytic fungus Pestalotiopsis sp., obtained from fruits of Drepanocarpus lunatus (Fabaceae) [12]. Active metabolites investigation of Talaromyces sp. (strain no. MH551540) associated with Xanthoparmelia angustiphylla afforded a new 3-methoxy-4,8-bihydroxymethyl-6-methyl-2,4,6-3-en-δ-lactone, talaromycin A 252 (Figure 9) [82]. Introducing an alien carbamoyltransferase (asm21) gene into the Streptomyces sp. CS by conjugal transfer, as a result, one recombinatorial mutant named CS/asm21-4 was successfully constructed. From the extracts of the CS/asm21-4 cultured on oatmeal solid medium, a new macrolide hookerolide 253 (Figure 9) was obtained [83]. Four new aromatic butenolides, asperimides A–D 254–257 (Figure 9), were isolated from solid cultures of a tropical endophytic fungus Aspergillus terreus. Compounds 254–257 represent the first examples of butenolides with a maleimide core isolated from Aspergillus sp. [84]. In ongoing search for bioactive metabolites from the genus of Aspergillus, four new butenolides, namely terrusnolides A–D 258–261 (Figure 9) were isolated from an endophytic Aspergillus from

![Chemical structures of penylpropanoids and their derivatives.](image-url)
Tripterygium wilfordii. Compound 258 was a butenolide derived by a triple decarboxylation. Furthermore, compounds 259–261 were the 4-benzyl-3-phenyl-5H-furan-2-one derivatives with an isopentene group fused to the benzene ring [85]. Chemical investigation on the culture extract of H. fuscum fermented on rice led to the isolation of one new 10-membered lactone 5,6-Epoxy-phomol 262 (Figure 9) [86]. Three new spirocyclic anhydride derivatives 263–265 (Figure 9) were isolated from the endophytic fungus Talaromyces purpurogenus obtained from fresh leaves of the toxic medicinal plant Tylophora ovate [87]. A new δ-lactone penicoffeazine A, 266 (Figure 9) was isolated from Penicillium coffeae MA-314, an endophytic fungus obtained from the fresh inner tissue of the leaf of marine mangrove plant Laguncularia racemosa [77]. On the basis of One Strain/Many Compounds (OSMAC) strategy, a new natural product 267 (Figure 9), was isolated from an endophytic fungus, Phomopsis sp. sh917, harbored in stems of Isodon eriocalyx var. laxiflora [43]. A chemical investigation on metabolites of Phyllosticta sp. J13-2-12Y isolated from the leaves of Acorus tatarinowii was carried out, which led to the isolation of four new phenylisotetronic acids, R-xenofuranone B 268 (Figure 9), S-xenofuranone B 269 (Figure 9), enantio-flflavipesin B 270 (Figure 9), and S-3-hydroxy-4,5-diphenylfuran-2(5H)-one 271 (Figure 9) [88]. An endophytic fungus Pestalotiopsis microspora isolated from the fruits of Manilkara zapota was cultured in potato dextrose broth media. Chromatographic separation of the EtOAc extract of the broth and mycelium led to the isolation of a new azaphilonoid named pitholide E 272 (Figure 9) [89].

Figure 9. Cont.
2.6. Anthraquinones

An endophytic fungus Penicillium citrinum Salicorn 46 isolated from Salicornia herbacea Torr., produced one new citrinin derivative, pencitrinol 273 (Figure 10) [90]. Lachnum cf. pygmaeum DAO0MC 250335 was obtained from ascospores originating from a collection of apothecia occurring on a dead P. rubens twig, from this strain, a new chlorinated paraquinone, chloromycorrhizinone A 274 (Figure 10) was isolated [58]. The endolichenic fungus Apiospora montagnei isolated from the lichen Cladonia sp. was cultured on solid rice medium, yielding a new xanthone derivative 8-hydroxy-3-hydroxymethyl-9-oxo-9Hxanthene-1-carboxylic acid methyl ether 275 (Figure 10) [37]. One previously undescribed metabolite anthraquinone derivative acetylquestinol 276 (Figure 10), was isolated from the culture of the endophytic fungus Eurotium chevalieri KUFA 0006 [62]. New pulvilloric acid-type azaphilones 277–280 (Figure 10) were produced by Nigrospora oryzae co-cultured with Irpex lacteus [14]. A new shunt product spiciferone F 281 (Figure 10) together with two new analogs spiciferones G 282 (Figure 10) and H 283 (Figure 10) were isolated from endophytic fungus Phoma betae inhabiting in plant Kalidium foliatum (Pall.) [91]. Bioassay-guided fractionation of the dichloromethane extract of the fungus Neofusicoccum austral SY SU-SKS024 led to the isolation of three new ethynaphthoquinone derivatives, neofusnaphthoquinone A 284 (Figure 10), 6-(1-methoxylethyl)-2,7-dimethoxyjuglone 285 (Figure 10), 3R,4R)-3-methoxyl-botryosphaerone D 286 (Figure 10), Neofusnaphthoquinone A 285 is the third example of the unsymmetrical naphthoquinone [92]. The EtOAc extract of strain Nectria pseudotrichia 120-1NP led to the identification of one new naph-
thoquinone, namely, nectriaquinone B 287 (Figure 10) [31]. Cytoskyrin C 288 (Figure 10), a new bisanthraquinone with asymmetrically cytoskyrin type skeleton, was isolated from an endophytic fungus ARL-09 (Diaporthe sp.) from Anoectochilus roxburghii [93]. Three new naphthomycins O–Q 289–291 (Figure 10), were obtained from the solid cultured medium of recombinatorial mutant strain CS/asm21-4 (By introducing an alien carbamoyltransferase (asm21) gene into the strain Streptomyces sp. CS (CS) by conjugal transfer) [83]. From the fermentation broth of the endophytic fungus Xylaria sp.SYPF 8246, one new compound, xylarianins B 292 (Figure 10) was isolated [94]. An undescribed substituted dihydroxanthene-1,9-dione, named funiculosone 293 (Figure 10), was isolated together from the culture filtrates of Talaromyces funiculosus (Thom) Samson, Yilmaz, Frisvad & Seifert (Trichocomaceae), an endolichenic fungus isolated from lichen thallus of Diorygma hieroglyphicum (Pers.) Staiger & Kalb (Graphidaceae), in India [95]. One new dihydroxanthene derivative globosuxanthone E 294 (Figure 10) was obtained from the crude extracts of two endophytic fungi Simplicillium lanosoniveum (J.F.H. Beyma) Zare & W. Gams (Sarocladium strictum) PSU-H168 and PSU-H261 which were isolated from the leaves of Hevea brasiliensis [96]. Two new naphthoquinone derivatives, 6-hydroxy-astropaquinone B 295 (Figure 10) and astropaquinone D 296 (Figure 10) were isolated from Fusarium napiforme, an endophytic fungus isolated from the mangrove plant, Rhizophora mucronata [97].

Figure 10. Cont.
2.7. Sterides

Two new steroids, (24R)-22, 23-dihydroxy-ergosta-4,6,8(14)-trien-3-one 23β-hydroxy-ergosta-7,22-diene-3β,5α,6β,9α-triol\[(22E,24R)-ergosta-7,22-diene-3β,5α,6β,9α-triol\] 306 (Figure 11), fusaristerols C [(22E,24R)-ergosta-7,22-diene-3β,5α,6β,9α-triol\] 307 (Figure 11), and fusaristerols D [(22E,24R)-ergosta-7,22-diene-3β,5α,6β,9α-tetraol 6-acetate] 308 (Figure 11), were isolated from the extract of endophytic fungus Aspergillus tubingensis YP-2 [103]. Three new methylated Δ8-pregnene steroids, stemphyllisteroids A–C 303–305 (Figure 11) were isolated from the medicinal plant Polyalthia laui-derived fungus Xylaria sp. AZGP4-2. The discovery of those three steroids is a further addition to diverse and complex array of methylated sterols [100]. Three new ergosterol derivatives, namely, fusaristerols B [(22E,24R)-3β-hydroxy-22, 23-dihydroxy-ergosta-4,6,8(14),20(22)-tetracos-3-one 23β-hydroxy-ergosta-7,22-diene-3β,5α,6β,9α-triol\] 306 (Figure 11), fusaristerols C [(22E,24R)-ergosta-7,22-diene-3β,5α,6β,9α-triol\] 307 (Figure 11), and fusaristerols D [(22E,24R)-ergosta-7,22-diene-3β,5α,6β,9α-tetraol 6-acetate] 308 (Figure 11), were isolated and characterized from the endophytic fungus Fusarium sp. isolated from Mentha longifolia L. (Labiatae) roots growing in Saudi Arabia [101]. A new ergosterol derivative, 23β-hydroxy-(20Z,24R)-ergosta-4,6,8(14),20(22)-tetraen-3-one 309 (Figure 11), was isolated from the co-culture between endophytic fungus Pleosporales sp. F46 and endophytic bacterium Bacillus wiedmannii Com1 both inhibiting in the medicinal plant Mahonia fortunei. This is the first example of isolation of a ergosterol derivative with a Δ20(22)-double bond in the side chain [102]. Two new sterol derivatives, namely, ergosterimide B 310 (Figure 11) and
demethylincisterol A5 311 (Figure 11), were isolated from the rice fermentation culture of Aspergillustubingensis YP-2 [105].

Figure 11. Chemical structures of sterides.

2.8. Other Types of Compounds

An endophytic fungus Talaromyces stipitatus SK-4 was isolated from the leaves of a mangrove plant Acanthus ilicifolius. Its crude extract exhibited significant antibacterial activity when purified to afford two new depsidones, talaromyones A and B 312–313 (Figure 12) [104]. Four new amide derivatives, designated as cordycepiamides A–D 314–317 (Figure 12), were isolated from the EtOAc-soluble fraction of the 95% EtOH extract of long-grain rice fermented with the endophytic fungus C. ninchukispora BCRC 31900, derived from the seeds of medicinal plant Beilschmiedia erythrophloia Hayata [105]. One new 4-hydroxycinnamic acid derivatives, methyl 2-[(E)-2-[4-(formyloxy)phenyl]ethenyl]-4-methyl-3-oxopentanoate 318 (Figure 12), was isolated from an EtOAc extract derived from a solid rice medium of endophytic fungal strain Pyronema sp. (A2-1 & D1-2) [106]. When endophytic fungus Phoma sp. nov. LG0217 isolated from Parkinsonia microphylla cultured in the absence of the epigenetic modifier, it produced a new metabolite, (S,Z)-5-(3′,4-dihydroxybutyliene)-3-propylfuran-2(5H)-one 319 (Figure 12) [107]. One new citrinin derivatives, pencitrin 320 (Figure 12) was isolated from an endophytic fungus P. citrinum 46 derived from Salicornia herbacea Torr by adding CuCl2 into fermentation medium [90]. Two new cytosporone derivatives 321–322 (Figure 12) were isolated from the endophytic fungus Phomopsis sp. PSU-H188 [108]. Extensive chemical investigation of the endophytic fungus, Fusarium solani JK10, harbored in the root of the Ghanaian medicinal plant Chlorophora regia, using the OSMAC (One Strain Many Compounds) approach resulted in the isolation of seven new 7′–desmethyl fusarin C derivatives 323–329 (Figure 12) [109]. A new biphenyl derivative 5,5′-dimethoxybiphenyl-2,2′-dial 330 (Figure 12), was isolated from the mangrove endophytic fungus Phomopsis longicolla HL-2232 [110]. A new hexanedioic acid analogue, (2S,5R)-2-ethyl-5-methylhexanedioic acid 331 (Figure 12), was isolated from Penicillium sp.
were isolated from the ethyl acetate extract [120]. Intriguingly, incorporation of Cu into a novel indene derivative (Figure 12), were obtained from the investigation of the endophytic fungus, Phoma herbarum (Figure 12), was isolated from an endophytic fungus, Phomopsis sp. sh917, harbored in stems of Isodon eriocalyx var. laxiflora [43]. Extracts from an endophytic fungus Dendrothyrium variisporum isolated from the roots of the Algerian plant Globularia alypum yielded three new anthranilic acid derivatives 339–341 (Figure 12) [60]. An endophytic fungal strain named Trichoderma atroviride was isolated from the bulb of Lycoris radiata. Following cultivation on rice medium, a novel 3-amino-5-hydroxy-5-vinyl-2-cyclopenten-1-one dimer, atricho dimer A 342 (Figure 12), was isolated. Compound 342 is the first example of cyclopentene dimer [11]. A new chaetoglobosin, penochalasin K 343 (Figure 12) bearing an unusual six-cyclic 6/5/6/5/6/13 fused ring system, was isolated from the solid culture of the mangrove endophytic fungus Penicillium chrysogenum V11 [114]. Three previously undescribed metabolites, including two prenylated indole 3-carbaldehyde derivatives 344–345 (Figure 12), an anthranilic acid derivative 346 (Figure 12) were isolated from the culture of the endophytic fungus Eurotium chevalieri KUFA 0006. The structures of compounds were established as (2-(2-methyl-3-en-2-yl)-1H-indole-3-carbaldehyde (344), (2,2-dimethylcyclopropyl)-1H-indole-3-carbaldehyde (345), 2{(2,2-dimethylbut-3-enyl)amino}benzoic acid (346) [62]. Nine previously undescribed depsidones simplicildones A–I 347–355 (Figure 12) were isolated from the endophytic fungus Simplicillium sp. PSU-H41 [65]. Six new compounds including four tyrosine derivatives terezine M 356 and phomarosines A–C 357–359 (Figure 12), and two new hydantoin derivatives, (S)-5-isopropyl-3-methoxyimidazolidine-2,4-dione 360 (Figure 12) and (S)-5-(4-hydroxybenzoyl)-3-isobutyrylimidazolidine-2,4-dione 361 (Figure 12), were obtained from the investigation of the endophytic fungus Phoma herbarum PSU-H256, which was isolated from a leaf of Hevea brasiliensis [115]. New mellein derivative; 4-methylmellein 362 (Figure 12) was isolated from the ethyl acetate extract of the endophytic fungus Penicillium sp. isolated from the leaf of Senecio flavus (Asteraceae) [116]. One novel cytochalasins, named jammosporin A 363 (Figure 12) was isolated from the culture of the endophytic fungus R. sanctae-crucciana, harboured from the leaves of the medicinal plant A. lebeek [117]. An endophytic fungus Arthrinium arundinis TE-3 was isolated and purified from the fresh leaves of cultivated tobacco (Nicotiana tabacum L.). Chemical investigation on this fungal strain afforded three new prenylated diphenyl ethers 364–366 (Figure 12) [118].

A novel indene derivative 367 (Figure 12), have been purified from an ethyl acetate extract of the plant-associated fungus Aspergillus flavipes Y-62, isolated from Suada glauca (Bunge) Bunge [119]. The endophytic fungus Mycosphaerella sp. (UFMGC2032) was isolated from the healthy leaves of Eugenia bimarginata, a plant from the Brazilian savanna. Two novel usnic acid derivatives, mycosurfurane 368 (Figure 12) and mycosniciodiol 369 (Figure 12), were isolated from the ethyl acetate extract [120]. Intriguingly, incorporation of Cu$^{2+}$ into the PDB medium of the endophytic fungus, Anteaglonium sp. FL0768 enhanced production of metabolites and drastically affected the biosynthetic pathway resulting in the production of pentaketide dimers, palmarumycin CE4 370 (Figure 12). The structure of palmarumycin CE4 370 was established as (28,4αα,5β,8β,8αα)-2,3,4,5,8,8α-hexahydro-5-hydroxy-spiro[2,8-epoxynaphthalene]-1(4H)-2′-naphtho[1,8-de][1,3]dioxin-4-one [121]. Three new compounds, including rotational isomers 371–372 (Figure 12) and 373 (Figure 12) were isolated from the solid cultures of the endophytic fungus Penicillium janthinellum SYPP 7899, compound 372 is the rotamer of 371 [122]. The chemical assessment of endophyte Phaeoleospora vochysiae sp. nov from Vochysia divergens, revealed a new compound 3-(sec-butyl)-6-ethyl-4,5-dihydroxy-2-methoxy-6-methylcyclohex-2-enone 374 (Figure 12) [123]. Co-cultivation of fungus Bionec-
tria sp. either with Bacillus subtilis or with Streptomyces lividans resulted in the production of two new o-aminobenzoic acid derivatives, bionectrimines A and B [375–376] (Figure 12) [70]. Chemical investigation on the solid rice culture of Trichoderma atroviride S361, an endophyte isolated from Cephalotaxus fortunei, has afforded a pair of novel N-furanone amide enantiomers, (−)-trichodermadione A [377] (Figure 12) and (+)-trichodermadione A [378] (Figure 12). The structure of 377 was identified as (4′R,2E)-N-(2-ethyl-5-methyl-3-oxo-2,3-dihydrofuran-2-yl)-5-hydroxy-3-methylpent-2-enamide [17]. Secondary metabolites were isolated from the fermentation broth of the endophytic fungus Xylaria sp. SYF 8246, including four new compounds, xylarianins A–D [379–382] (Figure 12), three new natural products, 6-methoxy-ycarbonyl-2′-methyl-3,5′,6′-tetramethoxy-diphenyl ether [383] (Figure 12), 2-chloro-6-methoxyycarbonyl-2′-methyl-3,5′,6′-tetramethoxy-diphenyl ether [384] (Figure 12), and 2-chlor-4′-hydroxy-6-methoxy carbonyl-2′-methyl-3,5′,6′-trimethoxy-diphenyl ether [385] (Figure 12) [94]. Bysspectin A [386] (Figure 12), a polyketide-derived octaketide dimer with a novel carbon skeleton, and two new precursor derivatives, bysspectins B and C [387–388] (Figure 12), were obtained from an organic extract of the endophytic fungus Byssochlamys spectabilis that had been isolated from a leaf tissue of the traditional Chinese medicinal plant Edgeworthia chrysantha [124]. Fusaristioamide B [389] (Figure 12), a new aminobenzamide derivative with unprecedented carbon skeleton was separated from Fusarium chlamydosporium EtOAc extract isolated from Anvillea garcinii (Burm.f.) DC. Leaves (Asteraceae) [125]. The study of endophytic fungus Annuolypoxylon stig- gium (Xylariaceae family) isolated from Bostychia radicans algae led to the isolation of a novel compound, 3-benzylidene-2-methylhexahydropyrrole [1,2-α] pyrazine-1,4-dione [390] (Figure 12) [126]. A new 2H-benzindazole derivative, alterindazolin A [391] (Figure 12), has been isolated from cultures of the endophyte Alternaria alternata Shm-1 obtained from the fresh wild body of Phellinus igniarius. The structure of 391 was elucidated for N-benzyl-3-[p-hydroxy phenoxoy]-benz[e]indazole [127]. One new penico acid derivative, named 1,1′-dioxine-2,2′-dipropionic acid [392] (Figure 12) and a new natural product, named 2-methylacetate-3,5,6-trimethylpyrazine [393] (Figure 12), were obtained from the Cladosporium sp. JS1-2, an endophytic fungus isolated from the mangrove Ceriporia tagal collected in South China Sea [128]. Chemical assessment of the new species Diaporthe vochysiae sp. nov. (LGMFI583), isolated as endophyte of the medicinal plant Vochysia divergens, revealed two new carboxamides, vochysiamides A [394] (Figure 12) and B [395] (Figure 12) [129]. Two new eremophilane derivatives lithocarins B [396] (Figure 12) and [397] (Figure 12), were isolated from the rice fermentation of fungus Xylaria longipes isolated from the sample collected at Ailao Moutain [130]. A new compound which was determined as 10-Ethylidene-2,4,9-trimethoxy-10,10a-dihydro-7,11-dioxa-benzo[b]heptalen-6,12-dione [403] (Figure 12) was isolated from Penicillium citrinum inhabiting Parmotrema sp. [131]. Investigation of the culture broth of Periconia macrospinosa KT3863 led to discover two new chlorinated mellins (3R,4S)-5-chloro-4-hydroxy-6-methoxymellein [404] (Figure 12), (R)-7-chloro-6-methoxy-8-O-methylmellein [405] (Figure 12) [132]. Two new compounds, lasdiplactone [406] (Figure 12) and lasdiploic acid [407] (Figure 12) were isolated from the chloroform extract of cell free filtrate of the endophytic fungus Lasiodiplodia pseudothelomaceae. The structure of 406 was characterized as (3S,4S,5R)-4-hydroxy-5,3′-dimethylidihydro-2′-furaneone [133]. Studies on the bioactive extract of mangrove endophytic fungus Pleosporales sp. SK7 led to the isolation of one new asterric acid derivative named methyl-2-(2-carbox-4-hydroxy-6-methoxylphenoxy)-6-hydroxy-4-methylbenzoate [408] (Figure 12) [23]. Chemical investigation of the mangrove-derived fungus Aspergillus sp. AV-2 following fermentation on solid rice medium led to the isolation of a new phenyl pyridazine derivative [409] (Figure 12) and a new prenylated benzoaldehyde derivative, dioxauroglaucin [410] (Figure 12) [134]. Three new furan derivatives, irpexlacte B–D [411–413] (Figure 12) were isolated from the endophytic fungus Irpex lacteus DR10-1 waterlogging tolerant plant Distylium chinense. Structures of compounds [411–413] were established as 5-(2α-hydroxypentyl) furan-2-carbaldehyde, 5-(1α-hydroxypentyl) furan-2-carbaldehyde,
5-(5-(2-hydroxypropanoyl) furan-2-yl) pentan-2-one, respectively [24]. Four new alkyl aromatics, penixylarins A–D 414–417 (Figure 12), were isolated from a mixed culture of the Antarctic deep-sea-derived fungus *Penicillium crustosum* PRB-2 and the mangrove-derived fungus *Xylaria* sp. HDN13-249. UPLC-MS data and an analysis of structural features showed that compounds 414 and 415 were produced by collaboration of the two fungi, while compounds 416–417 could be produced by *Xylaria* sp. HDN13-249 alone, but noticeably increased quantities by co-cultivation [135]. The co-culture of marine red algal-derived endophytic fungi *Aspergillus terreus* and *Paecilomyces lilacinus* induced the production of a new terrein derivative, namely asperterrein 418 (Figure 12) [136]. The co-culture of marine red algal-derived endophytic fungi *Aspergillus terreus* EN-539 and *Paecilomyces lilacinus* EN-531 induced the production of a new terrein derivative, namely asperterrein 418 (Figure 12) [136]. Fractionation and purification of the ethyl acetate extract of *Diaporthe lithocarpus*, an endophytic fungus from the leaves of *Artocarpus heterophyllus*, yielded one new compound, diaporthindoic acid 419 (Figure 12) [137]. A new diketopiperazine cyclo-(L-Phe-N-ethyl-L-Glu) 420 (Figure 12), was isolated from the cultures of an endophytic fungus *Aspergillus aculeatus* F027 [138]. Four novel compounds with g-methylidene-spirobutanolide core, fusaspirols A–D 421–424 (Figure 12), were isolated from the brown rice culture of *Fusarium solani* B-18. Compound 422 was found as the regioisomer of 421 [139]. One new polyacetylene glycoside 425 (Figure 12), one new brasilane-type sesquiterpenoid glycoside 426 (Figure 12), and two novel isobenzofuran-1(3H)-one derivatives 427–428 (Figure 12) were isolated from the solid culture of the endolichenic fungus *Hypoxylon fuscu* [86]. Chemical investigation of the crude extracts of both endophytic fungi *Simplicillium lanosoveum* (J.F.H. Beyma) Zare & W. Gams PSU-H168 and PSU-H261 resulted in the isolation of three new compounds including two depidiones, simplicildones J and K 429–430 (Figure 12) and one dihydroxanthenone derivative, globosuxanthone E 431 (Figure 12) [96]. One new cyclic tetrapeptide, 18-hydroxydihydrotentoxin 442 (Figure 12), and a new amide, 6-hydroxynamidin 443 (Figure 12) were obtained from the endophytic fungus *Phomopsis* sp. D15a2a isolated from the plant *Alternanthera bettzickiana* [55]. From an endophytic microorganism, *Aureobasidium pullulans* AJF1, harbored in the flowers of *Aconitum carmichaeli*, two unique lipid type new compounds (3R,5R)-3-(((3R,5R)-3,5-dihydroxydecanoyl)oxy)-5-hydroxydecanoic acid 444 (Figure 12), and (3R,5R)-3-(((3R,5R)-5-(((3R,5R)-3,5-dihydroxydecanoyl)oxy)-3-hydroxydecanoyl)oxy)-5-hydroxydecanoic acid 445 (Figure 12) were obtained [141]. The fungal strain *Alternaria alternata* JS0515 was isolated from *Vitex rotundifolia* (beach vitex). From the fungus one new altensusin derivative 446 (Figure 12), was isolated [142]. An investigation of a co-culture of the *Armillaria* sp. and endophytic fungus *Epicoccum* sp. YUD17002 associated with *Gastrodia elata* led to the isolation three aryl esters 447–449 (Figure 12) [27].
Figure 12. Cont.
Figure 12. Cont.
Figure 12. Cont.
Figure 12. Cont.
3. Biological Activity

3.1. Antimicrobial Activity

3.1.1. Antifungal Activity

New polyketide-terpene hybrid metabolites 1 and 5 were tested for their inhibition activity following the NCCLS recommendations against six phytopathogenic fungi Botrytis cinerea (ACCC 37347), Verticillium dahliae (ACCC 36916), Fusarium oxysporum (ACCC 37438), Alternaria solani (ACCC 36023), Fusarium gramineum (ACCC 36249), and Rhizoctonia solani (ACCC36124) obtained from Agricultural Culture Collection of China (ACCC). The antifungal assay displayed that 1 and 5 exhibited pronounced biological effects against F. oxysporum with MIC (minimum inhibitory concentration) value of 8 g/mL, whereas 5 can potently inhibited F. gramineum at concentration of 8 g/mL, compared with the positive control ketoconazole (MIC value of 8 g/mL) [9].

Compounds 15–16 were evaluated for antifungal activities against six fungal strains, including Rhizoctonia solani, Verticillium dahliae Kleb, Helminthosporium maydis, Fusarium oxysporum, Botryosphaeria berengeriana and Colletotrichum acutatum Simmonds. Both compounds displayed moderate activities against three fungal strains Verticillium dahliae Kleb, Helminthosporium maydis, and Botryosphaeria dothidea with MIC values of 25–50 μg/mL [15].

The inhibitory activities of compounds 17–20 against four phytopathogenic fungi, including Phytophthora infestans (late blight), Alternaria solani (early blight), Rhizoctonia solani (black scurf), Fusarium oxysporum (blast), were evaluated. Compounds 17–20 all showed potent inhibitory activities toward A. solani and F. oxysporum with MIC value of 16 μg/mL, 32 μg/mL, 8 μg/mL, 8 μg/mL and 32 μg/mL, 16 μg/mL, 16 μg/mL, 16 μg/mL, respectively, while 19–20 weakly inhibited P. infestans and R. solani with MIC value of 128 μg/mL, 64 μg/mL and 128 μg/mL, 32 μg/mL, respectively. Hygromycin B was used as Positive control (MIC values of P. infestans, A. solani, R. solani, and F. oxysporum were 8 μg/mL, <4 μg/mL, 8 μg/mL, 64 μg/mL, respectively) [16].

Antifungal activity of compounds 50–55 against 14 plant-pathogenic fungi Alternaria solani QDAU-14 (AS), Bipolaris sorokiniana QDAU-7 (BS), Ceratobasidium cornigerum QDAU-8 (CC), C. gloeosporioides Penz QDAU-9 (CG), Fusarium graminearum QDAU-10 (FG), F. oxysporum f. sp. cucumebrium QDAU-16 (FOC), F. oxysporum f. sp. momordicae QDAU-17 (FOM), F. oxysporum f. sp. radicis lycopersici QDAU-5 (FOR), F. solani QDAU-15 (FS), Glomerella cingulate QDAU-2 (GC), Helminthosporium maydis QDAU-18 (HM), Penicillium digitatum QDAU-11 (PD), P. piricola Nose QDAU-12 (PP), and Valsa mali QDAU-13 (VM) were carried out by the microplate assay. Compound 50 exhibited inhibitory activity against the 13 test fungi with MIC values of 4 μg/mL (AS), 1 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL (BS), 16 μg/mL (CC), 8 μg/mL (CG), 8 μg/mL (FG), 1 μg/mL (FOC), 2 μg/mL (FOM), 64 μg/mL (FOR), 4 μg/mL
(FS), 1 µg/mL (GC), 8 µg/mL (PD), 4 µg/mL (PP), 16 µg/mL (VM), respectively, while compounds 50–55 showed activity against *Fusarium oxysporum* f. sp. cucumerinum with MIC values ranging from 1 to 64 µg/mL. 51 exhibited inhibitory activity against the 6 test fungi with MIC values of 32 µg/mL (AS), 8 µg/mL (BS), 32 µg/mL (FS), 4 µg/mL (GC), 8 µg/mL (PD), 4 µg/mL (PP), respectively. 52 exhibited inhibitory activity against the 4 test fungi with MIC values of 64 µg/mL (FOR), 1 µg/mL (GC), 8 µg/mL (PP), 32 µg/mL (VM), respectively. 53 exhibited inhibitory activity against the 3 test fungi with MIC values of 64 µg/mL (FOR), 16 µg/mL (PD), 1 µg/mL (PP), respectively. 54 exhibited inhibitory activity against Helminthosporium maydis with MIC value of 16 µg/mL. 55 exhibited inhibitory activity against *P. piricola* Nose with MIC values of 4 µg/mL (AS). Amphotericin B was used as the positive control against fungi with MIC values of 2 µg/mL (AS), 0.5 µg/mL (BS), 8 µg/mL (CC), 0.5 µg/mL (CG), 2 µg/mL (FG), 0.5 µg/mL (FOC), 1 µg/mL (FOM), 2 µg/mL (FOR), 4 µg/mL (FS), 0.5 µg/mL (GC), 2 µg/mL (HM), 2 µg/mL (PD), 2 µg/mL (PP), 8 µg/mL (VM), respectively [25].

Compounds 68–74 were assayed for their antifungal activities against *C. albicans*. Geneticin (G418), was used as positive control with the MIC value of 6.3 µg/mL. Compound 69 displayed inhibitory effect against *C. albicans* with an MIC value of 12.5 µg/mL, while compounds 68 and 74 exhibited weak inhibitory effect against *C. albicans* with MIC values of 100 µg/mL and 150 µg/mL [32].

Antifungal activities (Minimum inhibitory concentrations; MICs) of the isolated metabolite 170 were determined using a serial dilution assay against *Mucor hiemalis* DSM 2656. Compound 170 showed moderate to weak antifungal activity against *Mucor hiemalis* DSM 2656 with a MIC value of 33.33 µg/mL [52].

One fungus *Candida albicans* (ATCC 10231) was used for antifungal tests, the results showed that compound 177 exhibited significant antifungal activity against *C. albicans* with the MIC value of 2.62 µg/mL. The positive control for antifungal tests was used by ketoconazole with MIC value of 0.10 µg/mL [54].

The methylated dihydropyrone 189 and compound 274 were tested for in vitro antifungal activity using the Oxford diffusion assay against *M. violaceum* (*Microbotryum violaceum*) and *S. cerevisiae* (*Saccharomyces cerevisiae*), 189 and 274 exhibited moderate antifungal activity, inhibiting the growth of *S. cerevisiae* and *M. violaceum* at 25 µg/mL. Nystatin was the positive control for antifungal assays, previous studies had shown the MIC values of nystatin in the *S. cerevisiae* culture used was 4 µg/mL and for *M. violaceum* was 2 µg/mL [58].

Minimum Inhibitory Concentration (MIC) assays were used to assess antifungal activity of the compounds against anti-phytopathogenic activity against seven pathogenic fungi *Alternaria alternata* (Aa), *Botrytis cinerea* (Bc), *Cochliobolus heterostrophus* (Ch), *Colletotrichum lagenarium* (Cl), *Fusarium oxysporum* (Fo), *Gaeumannomyces graminis* (Gg), and *Thielaviopsis basicola* (Tb). Compound 227 showed potent and specific activity against 4 fungi with MIC values of 32 µg/mL(Bc), 16 µg/mL(Ch), 8 µg/mL(Fo), 8 µg/mL(Tb), respectively, whereas compound 228 showed moderate activity against 3 fungi with MIC values of 16 µg/mL(Bc), 32 µg/mL(Ch), 32 µg/mL(Fo) respectively. Prochloraz, a commercialized broad-156 spectrum fungicide widely used in agriculture, was used as positive antifungal control with MIC values of 8 µg/mL(Bc), 16 µg/mL(Ch), 8 µg/mL(Fo), 8 µg/mL(Tb), respectively. To the best of our knowledge, this is the first study to show that PIAs exhibit inhibitory activity against plant-pathogenic fungi [74].

Prochaetoviridin A 230 was evaluated for its antifungal activities against 5 pathogenic fungi *S. sclerotiorum*, *B. cinerea*, *F. graminearum*, *P. capsici* and *F. moniliforme* at the concentration of 20 µg/mL. It showed moderate antifungal activity with inhibition rates ranging from 13.7% to 39.0% [69].

Compounds 244 and 245 were evaluated against phytopathogenic fungi *Cladosporium cladosporioides* and *C. sphaerospermum* (*Cladosporium sphaerospermum*) using direct bioautography. The results showed that 244 exhibited antifungal activity, with a detection limit of 5 µg, for both fungi, while compound 245 displayed weak activity (detection limit > 5 µg),
with a detection limit of 25 µg. Nystatin was used as a positive control, showing a detection limit of 1 µg [80].

Compound 266 was tested for antimicrobial activities against two plant-pathogenic fungi Fusarium oxysporum f. sp. momordicae nov. f. and Colletotrichum gloeosporioides, and exhibited potent activity against both strains with MIC values of 5 µM, which was close to that of the positive control, amphotericin B (MIC = 0.5 µM) [77].

Compounds 289–291 were assayed for antifungal activity against phytopathogenic fungi M. grisea and F. verticillioides, they showed evident inhibition of phytopathogenic fungi. The MIC values of compounds 289–291 were 200 µg/mL, 50 µg/mL and 50 µg/mL against M. Grisea and 200 µg/mL, 100 µg/mL and 100 µg/mL against F. verticillioides. Hygromycin B was the positive control against fungus with the MIC values of 50 µg/mL against both M. Grisea and F. verticillioides [83].

The purified metabolite 293 was tested for antimicrobial activity against selected pathogens namely C. albicans. Funiculosone (293) displayed antimicrobial activity inhibiting fungal pathogens. Funiculosone was able to inhibit the growth of C. albicans with an IC50 (50% inhibitory concentration) of 35 µg/mL [95].

Antifungal activity was determined against C. neoforms ATCC90113. The results showed that globosuxanthone E 294 displayed antifungal activity against Cryptococcus neoforms ATCC90113 with the MIC value of 32 µg/mL. Amphotericin B was used as a positive control for antifungal activity and exhibited an MIC value of 0.5 µg/mL [96].

The new compound, penochalasin K 343 was tested for its antifungal activity against four phytopathogenic fungi including C. musae, C. gloeosporioides, P. italicum, and K. solani. Compound 343 displayed excellent selective activities against the two phytopathogenic fungi Colletotrichum gloeosporioides (Penz) Sacc. (C. gloeosporioides), and Rhizoctonia solani Kühn (R. solani), with MIC values of 6.13 µM and 12.26 µM, respectively. Moreover, the activity towards C. gloeosporioides and R. solani were about ten-fold and two-fold better than those of the positive control carbenazidam, respectively. Whereas only moderate or weak inhibitory activities were exhibited by compound 343 towards Colletotrichum musae (Berk. and M. A. Curtis) Arx. (C. musae) and Penicillium italicum Wehme (P. italicum), Carbenazidam and the solvent were adopted as positive and negative control, respectively. The MIC values of Carbenazidam against C. gloeosporioides, R. solani, C. musae and P. italicum were 65.38 µM, 32.69 µM, 32.69 µM and 16.34 µM [114].

The isolated compound 349 was evaluated for antifungal activities against C. neoforms and P. marneffei, it displayed weak antifungal activity against C. neoforms with MIC value of 32 µg/mL. Amphotericin B was used as positive control for fungi, displayed the MIC values of 1.0 µg/mL and 2.0 µg/mL against C. neoforms and P. marneffei [63].

Three fungi (Aspergillus flavus, Fusarium oxysporum and Candida albicans) were used in antifungal activity tests by disk diffusion method, the antifungal activity was recorded as clear zones of inhibition surrounding the disc (mm). Compound 362 showed antifungal activity against F. oxysporum (zone of inhibition was 6 mm) and variable activities against A. flavus and the yeast C. albicans (zone of inhibition was 5 mm). Nystatin (10 mg/disc) was used as standard antifungal (zone of inhibition against A. flavus and F. oxysporum were 12 mm and 17 mm) [116].

The antifungal activity against six commonly occurring plant-pathogenic fungi Alternaria alternata, Cochliobolus heterostrophus, Gaeumannomyces graminis, Glomerella cingulata, Mucor hiemalis, and Thielaviopsis basicola of compounds 364–365 were evaluated. Compounds 364 and 365 showed selective antifungal activity against Mucor hiemalis with minimum inhibitory concentration (MIC) values of 8 µg/mL and 4 µg/mL, respectively. Prochloraz was used as positive control with MIC value of 8 µg/mL against Mucor hiemalis [118].

In search for novel antifungal compounds, 368 and 369 were tested against C. neoforms and C. gattii. Compounds 368 and 369 exhibited moderate antifungal activities against Cryptococcus neoforms and Cryptococcus gattii, each with minimum inhibitory concentration values of 50.0 µg/mL and 250.0 µg/mL, respectively [120].
The antifungal activity of the compound 374 were evaluated against fungal strains *Phyllosticta citricarpa* LGMF06 and *Colletotrichum abscissum* LGMF1268 in order to select the best culture conditions to produce bioactive secondary metabolites. The isolated compound 374 displayed antifungal activity against the citrus phytopathogen *Phyllosticta citricarpa* with the inhibition zone of 30 mm. Amphotericin B was used as positive control with the inhibition zone of 37 mm [123].

The antifungal effect of 389 was assessed by agar disc diffusion assay towards *Candida albicans* (AUMC No. 418), *Geotrichum candidum* (AUMC No. 226), and *Trichophyton rubrum* (AUMC No. 1804) as fungi. It exhibited selective antifungal activity towards *C. albicans* (MIC 1.9 μg/mL and IZD 14.5 mm), comparing to the antifungal standard clotrimazole (MIC 2.8 μg/mL and IZD 17.9 mm), whilst, it had moderate activity against *G. candidum* (MIC 6.9 μg/mL and IZD 28.9 mm) [125].

Compound 418 was tested for antimicrobial activities against five plant-pathogenic fungi *A. brassicaceae*, *Colletotrichum gloeosporioides*, *Fusarium oxysporum*, *Gaumannomyces graminis*, and *P. piricola*. It exhibited inhibitory activity against *A. brassicaceae* and *P. piricola* with the same MIC value of 64 μg/mL. The positive control against *A. brassicaceae* and *P. piricola* was amphotericin B with MIC values of 4 μg/mL and 8 μg/mL respectively [136].

Antifungal activity was determined against *C. neoformans* ATCC90113. Simplicilidone K 430 and globosuxanthone E 431 displayed weak antifungal activity against *Cryptococcus neoformans* ATCC90113 with the same MIC values of 32 μg/mL. Amphotericin B was used as a positive control for antifungal activity and exhibited an MIC value of 0.5 μg/mL against *C. neoformans* ATCC90113 [96].

### 3.1.2. Antibacterial Activity

The new compound 9 was evaluated for its antibacterial activities against *Mycobacterium tuberculosis*, *Staphylococcus aureus* (ATCC25923), *S. aureus* (ATCC700699), *Enterococcus faecalis* (ATCC29212), *E. faecalis* (ATCC51299), *E. faecium* (ATCC35667), *E. faecium* (ATCC700221) and *Acinetobacter baumannii* (ATCCBAA1605). It showed very weak inhibitory effect against *M. tuberculosis* (MIC > 50 μM) [12].

Compounds 15–16 were also evaluated for their antibacterial activity against twelve bacteria strains, including *Micrococcus lysodeikticus*, *Bacillus subtilis*, *Bacillus cereus*, *Micrococcus luteus*, *Staphylococcus aureus*, *Bacillus megaterium*, *Bacterium paratyphosum B*, *Proteus bacillim vulgaris*, *Salmonella typhi*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Enterobacter aerogenes*. Compounds 15–16 displayed moderate activities against three bacterial strains (*Bacillus subtilis*, *Bacillus cereus* and *Escherichia coli*) with MIC values of 25–50 μg/mL [15].

Compounds 23–24, 26 and 28 were evaluated for their antimicrobial activities against the Gram-positive strains *Staphylococcus aureus* ATCC 25923 and *Mycobacterium smegmatis* ATCC 607, Gram-negative strains *Escherichia coli* ATCC 8739 and *Pseudomonas aeruginosa* ATCC 9027, by the liquid growth inhibition in 96-well microplates. Compounds 23–24, 26 and 28 displayed mild antibacterial activities against the Gram positive strain *Staphylococcus aureus* ATCC 25923 with IC₅₀ values ranging from 31.5 to 41.9 μM [18].

New compounds 49, 411–413 were evaluated for antibacterial activity against *P. aeruginosa* (CMCC(B)10,104). Compared with the positive control (Gentamicin, 0.18 μM), compounds 49, 411–413 showed moderate activity with MIC values of 24.1 μM, 32.3 μM, 35.5 μM and 23.8 μM respectively [24].

Antimicrobial evaluation against one human pathogen *Escherichia coli* EMBLC-1 (EC), 10 marine-derived quatic bacteria *Aeromonas hydrophila* QDIO-1 (AH), *Edwardsiella tarda* QDIO-2 (ET), *E. ichtharida* QDIO-10, *Micrococcus luteus* QDIO-3 (ML), *Pseudomonas aeruginosa* QDIO-4 (PA), *Vibrio alginolyticus* QDIO-5, *V. anguillarum* QDIO-6 (VAn), *V. harveyi* QDIO-7 (VH), *V. parahaemolyticus* QDIO-8 (VP), and *V. vulnificus* QDIO-9 (VV), was carried out by the microplate assay. Compound 50 showed activity with the same MIC value of 8 μg/mL against 4 bacteria ((EC) (AH) (PA) and (VH)) and the value of 4 μg/mL against *V. parahaemolyticus*. Compound 51 showed activity with the MIC values of 16 μg/mL (EC), 8 μg/mL (PA) and 16 μg/mL (VH). Compound 52 showed activity with the MIC
values of 8 µg/mL (EC), 8 µg/mL (AH), 4 µg/mL (PA), 2 µg/mL (VH) and 8 µg/mL (VP). While compound 55 had activity against aquatic pathogens Edwardsiella tarda and Vibrio anguillarum with MIC values of 1 µg/mL and 2 µg/mL, respectively, comparable to that of the positive control chloramphenicol (2 µg/mL (EC), 4 µg/mL (AH), 0.5 µg/mL (ET), 4 µg/mL (ML), 2 µg/mL (PA), 1 µg/mL (VAn), 1 µg/mL (VH), 4 µg/mL (VP), 1 µg/mL (VV)) [25].

Compounds 66 and 116 were evaluated for their antimicrobial activities against three human pathogenic strains (Escherichia coli ATCC 25922, Staphylococcus aureus ATCC 25923 and Candida albicans ATCC 10231) by microbroth dilution method in 96-well culture plates. Bioassay results indicated that compound 116 displayed potent activity against Staphylococcus aureus with an MIC value of 6.25 µM, which was equal to that of ampicillin sodium as a positive control, and compound 66 had a moderate inhibitory effect on S. aureus with an MIC value of 25.0 µM [30].

Compounds 70 and 74 were assayed for their antimicrobial activities against S. aureus, B. cereus, B. subtilis, P. aeruginosa, and K. pneumonia. The results showed that compounds 70 and 74 displayed weak antimicrobial effects with the same MIC value of 100 µg/mL against B. subtilis and S. aureus. Ampicillin was used as positive control with MIC values of 8 µg/mL and 3.5 µg/mL against S. aureus and B. subtilis [32].

Compound 119 was evaluated for antibacterial activities in vitro against Gram-Positive and Gram-Negative Bacteria (Staphylococcus aureus (DSM 799), Escherichia coli (DSM 1116), Escherichia coli (DSM 682), Bacillus subtilis (DSM 1088) and Acinetobacter sp. (DSM 586)). It was active against Staphylococcus aureus with an MIC value of 0.1 µg/mL. Streptomycin and Gentamicin were used as references against Staphylococcus aureus with MIC values of 5.0 µg/mL and 1.0 µg/mL, respectively. Comparison of 119 with 118 (10.0 µg/mL against Staphylococcus aureus) and confirmed that the substitution at C-11 plays an important role in increasing the antibacterial activity against the selected bacterium [42].

The antibacterial activity of 157 and 159 was evaluated against five pathogenic bacteria of Micrococcus tetragenus, Staphylococcus aureus, Streptomyces albus, Bacillus cereus, and Bacillus subtilis. Compound 157 showed potent antimicrobial activity against B. cereus with the MIC value of 12.5 µg/mL, Compound 159 also showed potent antimicrobial activities against B. subtilis, S. aureus, and S. albus with the same MICs value of 12.5 µg/mL. Ciprofloxacin was used as a positive control with MIC values of 6.15 µg/mL, 5.60 µg/mL, 0.20 µg/mL, 1.50 µg/mL and 6.15 µg/mL against M. tetragenus, B. cereus, B. subtilis, S. aureus and S. albus [49].

The antimicrobial activity was determined by the paper disk diffusion method (100 µg compound in 8 mm paper disk), using meat peptone agar for Staphylococcus aureus and Pseudomonas aeruginosa, peptone yeast agar for Candida albicans, and potato dextrose agar for Aspergillus clavatus. 164 showed moderate antibacterial activity against Staphylococcus aureus NBRC 13276 (5: 24 mm) at a concentration of 100 µg/disk (MIC value: 3.2 µg/mL). Chloramphenicol was used for positive control against S. aureus (1 µg/mL) [50].

Antimicrobial activities (Minimum inhibitory concentrations; MICs) of the isolated metabolite 170 was determined using a serial dilution assay against Bacillus subtilis DSM 10, Chromobacterium violaceum DSM 30191, Escherichia coli DSM 1116, Micrococcus luteus DSM 1790, Pseudomonas aeruginosa DSM PA14, Staphylococcus aureus DSM 346, and Mycobacterium smegmatis DSM ATCC700084. Compound 170 showed moderate antibacterial activity against Staphylococcus aureus DSM 346 and Bacillus subtilis DSM 10, respectively, with a MIC value of 33.33 µg/mL. Oxytetracyclin was used as positive control with MIC values of 0.2 µg/mL and 4.16 µg/mL against Staphylococcus aureus DSM 346 and Bacillus subtilis DSM 10, respectively [52].

Antimicrobial tests were used for the disc diffusion method. Two Gram-positive methicillin-resistant Staphylococcus aureus, Bacillus subtilis (ATCC 6633), two Gram-negative pseudomonas aeruginosa (ATCC 9027), Salmonella typhimurium (ATCC 6539), were used. Compound 176 showed strong antibacterial activity against the P. aeruginosa and MRSA with the MIC values of 1.67 µg/mL and 3.36µg/mL, respectively. Compound 177 exhibited significant antibacterial activity against B. subtilis with the MIC value of 5.25 µg/mL.
Positive control for antifungal tests were used by Ampicillin with the MIC values of 0.15 μg/mL, 0.15 μg/mL and 0.07 μg/mL against P. aeruginosa, MRSA (Methicillin-resistant Staphylococcus aureus) and B. subtilis, respectively. The results indicated that the methylester displayed improved biological activity and showed a selective antibacterial activity against P. aeruginosa and MRSA. Compound 176 exhibited more strong antimicrobial activity than compound 177 [54].

Antibacterial activity was determined against five pathogenic bacteria Escherichia coli (ATCC 25922), Staphylococcus aureus (ATCC 25923), Bacillus cereus (ATCC 11778), Staphylococcus epidermidis (ATCC 12228) and Pseudomonas albus (ATCC 8799) by the microplate assay method. Compound 208 showed weak antibacterial activity against Staphylococcus aureus with a MIC value of 20 μg/mL. Ciprofloxacin was used as the positive control [66].

Antimicrobial activity testing of the compound 212 was carried out against a set of microorganisms using paper-disk diffusion assay. 212 exerted moderate-high activities (13 mm, 16 mm, 15 mm, 10 mm, 11 mm and 14 mm) against Staphylococcus aureus, Pseudomonas aeruginosa, Candida albicans, Saccharomyces cerevisiae, Bacillus cereus and Bacillus subtilis ATCC 6633. Gentamycin was used as positive control with the diameter of agar diffusion of 22 mm, 18 mm, 17 mm, 23 mm, 20 mm and 18 mm against the 5 bacteria as mentioned above [68].

Minimum Inhibitory Concentration (MIC) assays were used to assess antibacterial activity of the isolated compounds 227–228 against human pathogens (Escherichia coli, Micrococcus luteus, and Pseudomonas aeruginosa) and plant pathogen (Ralstonia solanacearum). Chloromycetin was used as a positive antibacterial control. Notably, compound 227 demonstrated potent activity against P. aeruginosa with an MIC value of 1 μg/mL, which was better than that of the positive control chloromycetin (MIC = 4 μg/mL). Compound 228 displayed activity against Micrococcus luteus and Pseudomonas aeruginosa with the same MIC value of 8 μg/mL (2 μg/mL and 4 μg/mL against Micrococcus luteus and Pseudomonas aeruginosa for Chloromycetin). In contrary to compounds 228 and the known compound A (Figure 13), B (Figure 13) showed stronger antibacterial activity (MIC values of 4, 4, 8, and 8 μg/mL against E. coli, M. luteus, P. aeruginosa, and R. solanacearum, respectively), indicating that hydroxylation at C-10 can augment antibacterial activity [74].

Figure 13. Chemical structures of known compounds.

Compound 229 was tested for in vitro antimicrobial activity against 2 bacteria B. subtilis (ATCC 23857), and E. coli (ATCC 67878). Chloramphenicol was the antibacterial positive control. 229 showed modest antibiotic activity to E. coli with an MIC value of 100 μg/mL [58].
Antimicrobial activities were determined against four terrestrial pathogenic bacteria, including *Pseudomonas aeruginosa*, *Methicillin-resistant Staphylococcus aureus*, *Bacillus subtilis* and *Escherichia coli* by the microplate assay method. Compound 231 exhibited modest antibacterial activity against *Escherichia coli* and *Pseudomonas aeruginosa* with 12.5 µg/mL, 50 µg/mL, respectively [75].

Antimicrobial activity was estimated by the inhibitory zone to five indicator microorganisms (*Bacillus subtilis CMCC 63501*, *Candida albicans CMCC 98001*, *Escherichia coli CMCC 44102*, *Pseudomonas aeruginosa CMCC 10104* and *Staphylococcus aureus CMCC 26003*). Compounds 237 and 238 exhibited growth inhibitory activity against *E. coli* with MIC values of 32 µg/mL. Chloramphenicol was used as positive control with an MIC value of 4 µg/mL against *E. coli* [76].

Compound 241 was tested for antibacterial activity against *Bacillus subtilis* (ATCC 6633), *Staphylococcus aureus* (CGMCC 1.2465), *Streptococcus pneumoniae* (CGMCC 1.1692), *Escherichia coli* (CMCC 1.2340), the results showed that 241 displayed modest antibacterial activity against *B. subtilis* with MIC value of 66.7 µM (the positive control gentamycin showed MIC value of 1.3 µM) [78].

Compound 246 was evaluated by the agar diffusion method against Gram-positive and Gram-negative bacteria, 246 showed moderate antibacterial activity against both *Pseudomonas aeruginosa ATCC 15442* (13 mm) and *Staphylococcus aureus NBRC 13276* (13 mm), respectively, at a concentration of 100 µg/disk [81].

Compounds 253, 289–291 were assayed for their antibacterial activities against *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella typhimurium*. All of the four compounds exhibited antibacterial activities against *Escherichia coli*, *Salmonella typhimurium*, and *Staphylococcus aureus* with the same MIC values of 25 µg/mL, 50 µg/mL and 25 µg/mL, respectively. Ampicillin was the positive control against bacteria, the MIC of ampicillin was lower than 0.78 µg/mL against *Salmonella typhimurium*, and *Staphylococcus aureus*, while the MIC value against *Escherichia coli* was 100 µg/mL [83].

The antimicrobial activity was determined by the paper disk diffusion method (100 µg compound in 8 mm paper disk), using meat peptone agar for *Staphylococcus aureus* and *Pseudomonas aeruginosa*. Compound 287 exhibited antibacterial activity against *S. aureus* and *P. aeruginosa* with MIC values (µg/mL) of >50 and 6.25. Chloramphenicol and kanamycin were used for positive control against *S. aureus* and *P. aeruginosa* (each 1 µg/mL), respectively [31].

Compound 293 was tested for antimicrobial activity against selected pathogens namely *S. aureus*, *E. coli* and *Pseudomonas aeruginosa*. *C. Gessard*. Funiculosone (293) displayed antimicrobial activity inhibiting the bacterial pathogens. Funiculosone was able to inhibit the growth of *E. coli*, *S. aureus* and *C. albicans* with IC₅₀ of 25 µg/mL and 58 µg/mL and 35 µg/mL respectively [95].

Compounds 295–296 were evaluated for antimicrobial activity against Gram-positive and Gram-negative bacteria. Compounds 295 and 296 showed moderate antibacterial activity against *S. aureus NBRC 13276* and *P. aeruginosa ATCC 15442* (MIC values of 6.3 µg/mL and 12.5 µg/mL for *S. aureus NBRC 13276*, 6.3 µg/mL and 6.3 µg/mL for *P. aeruginosa ATCC 15442*) [97].

Compounds 303–304 were evaluated for their antibacterial activities against six pathogenic bacteria including *M. tetragenus*, *S. aureus*, *S. albus*, *B. cereus*, *B. subtilis*, *E. coli*. Compound 303 showed antibacterial activity against *E. coli* with the MIC value of 6.25 µg/mL, and 304 exhibited a broad spectrum of antibacterial activities against six pathogenic with the MIC value ranging from 12.5 to 50 µg/mL (MIC values: 50 µg/mL for *M. tetragenus*, 25 µg/mL for *S. aureus*, >50 µg/mL for *S. albus*, 25 µg/mL for *B. cereus*, 12.5 µg/mL for *B. subtilis* and 50 µg/mL for *E. coli*). Ciprofloxacin was used as a positive control (MIC values: 0.313 µg/mL for *M. tetragenus* and *S. aureus*, 0.625 µg/mL for *S. albus*, *B. cereus*, *B. subtilis* and *E. coli*) [100].

The antibacterial activities of pure compound 309 was evaluated against Gram-positive bacteria *Staphylococcus aureus* and *Bacillus subtilis* and Gram-negative bacteria *Pseudomonas aeruginosa* and *Escherichia coli* using the disk diffusion assay. The new com-
Vibrio anguillarum was determined by the conventional broth dilution assay. 100 µ with MIC value of 32 µ were 4.16 µ with MIC values of 8.33 µ with an MIC value of 12.5 ATCCBAA-535. Although rifampin as positive control showed significantly in vitro antibacterial activity against Mycobacterium marinum ATCCBAA-535. Although rifampin as positive control showed significantly in vitro antibacterial activity against Mycobacterium marinum ATCCBAA-535 with IC₅₀ of 2.1 µM, compound 318 also exhibited potential inhibitory activity with IC₅₀ of 64 µM [106].

The antibacterial activities of the isolated compounds 325–329 were evaluated against the soil bacterium Acinetobacter sp. BD4 (Gram–negative), the environmental strain of Escherichia coli (Gram–negative), as well as human pathogenic strains of Staphylococcus aureus (Gram–positive) and Bacillus subtilis (Gram–positive). The standard references employed were streptomycin (MIC values: 1.0 µg/mL against Escherichia coli, 10.0 µg/mL against Acinetobacter sp. BD4) and gentamicin (MIC values: 1.0 µg/mL against Escherichia coli, 5.0 µg/mL against Acinetobacter sp. BD4). Compounds 325–326 and 328, demonstrated pronounced activity at 10.0 µg/mL against the soil bacterium Acinetobacter sp. BD4 comparable to streptomycin. Compounds 327 and 329 displayed antibacterial efficacies against Escherichia coli with the same MIC value of 5.0 µg/mL [109].

Antibacterial activity of the new compound 330 against Vibrio parahaemolyticus and Vibrio anguillarum was determined by the conventional broth dilution assay. 330 showed moderate inhibitory effects on Vibrio parahaemolyticus with an MIC value of 10 µg/mL. Ciprofloxacin was used as a positive control [110].

Antibacterial efficacies of the metabolite 339 were determined by serial dilution assay. Compound 339 showed strong activity against Bacillus subtilis and Micrococcus luteus with MIC values of 8.33 µg/mL and 16.66 µg/mL, respectively, while the MIC values of Oxytetracyclin used as the positive control against Bacillus subtilis and Micrococcus luteus were 4.16 µg/mL and 0.40 µg/mL, respectively. While the MIC value of compound C (Figure 13) against Mucor hiemalis (16.66 µg/mL) was the same as that of nystatin used as positive control. The two active metabolites are anthranilic acid derivatives with a phenylethyl core. Since metabolite 340, which contains a phenylmethyl group instead of a phenylethyl residue, was not active, it was concluded that the phenylethyl moiety in compounds 339 and C is essential for their antimicrobial activity [60].

The isolated compound 347, which was obtained in sufficient amounts, was evaluated for antimicrobial activities against S. aureus ATCC25923 and methicillin-resistant S. aureus. Simplicidione A 347 displayed weak antibacterial against Staphylococcus aureus with MIC value of 32 µg/mL. Vancomycin which was used as positive control for bacteria, displayed the MIC values of 0.5 µg/mL and 1.0 µg/mL against both S. aureus and methicillin-resistant S. aureus [63].

The antimicrobial activity of compound 367 was evaluated using the strains of methicillin-resistant Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa, Bacillus subtilis, and Escherichia coli. Compound 367 exhibited weaker activity in comparison to the positive control tetracycline against methicillin-resistant S. aureus (MRSA) with the MIC value of 128 µg/mL, and against K. pneumoniae and P. aeruginosa with equal MIC values of 32 µg/mL [119].

Compounds 371–373 were assayed for their antimicrobial activities against Staphylococcus aureus, Bacillus subtilis, Pseudomonas aeruginosa, Klebsiella pneumonia and Escherichia coli. Compounds 371–372 exhibited significant inhibitory activities against B. subtilis and S. aureus with MIC values of 15 µg/mL and 18 µg/mL, respectively. Compound 373 showed moderate inhibitory activities against B. subtilis (MIC 35 µg/mL) and S. aureus
(MIC 39 µg/mL). Ampicillin (MIC values: 8 µg/mL, 3.5 µg/mL, 10 µg/mL, 10 µg/mL and 2.5 µg/mL against the 5 bacteria mentioned above) and kanamycin (MIC values: 4 µg/mL, 1.0 µg/mL, 8 µg/mL, 9 µg/mL and 4 µg/mL against the 5 bacteria mentioned above) served as the positive control. In addition, morphological observation showed the rod-shaped cells of *B. subtilis* growing into long filaments, which reached 1.5- to 2-fold of the length of the original cells after treatment with compounds 371–372. The coccoid cells of *S. aureus* exhibited a similar response and swelled to a 2-fold volume after treatment with compounds 371–372 [122].

The antimicrobial activity of the compound 374 was evaluated against the Gram-positive bacteria *Staphylococcus aureus* (ATCC 25923), methicillin-resistant *Staphylococcus aureus* (MRSA) (BACHC-MRSA). The resulting inhibition zones were measured in millimeters. 374 displayed antibacterial activity against sensitive and resistant *S. aureus*, the diameter of inhibition zone was 14 mm, Ampicillin was antibacterial control with the diameter of inhibition zone of 30 mm [123].

Compounds 388 was tested for its antimicrobial activities against *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923, *Staphylococcus epidermidis* ATCC 12228, and *Mycobacterium Smegmatis* ATCC 27154. Compound 388 was active against *Escherichia coli* ATCC 25922 and *Staphylococcus aureus* ATCC 25923 with MIC values of 32 µg/mL and 64 µg/mL, respectively. Levofloxacin was used as a positive control with MIC value of 0.12 µg/mL [124].

Fusaridioamide B 389 has been assessed for antibacterial activities towards various microbial strains (*Staphylococcus aureus* (AUMC No. B-54) and *Bacillus cereus* (AUMC No. B-5)) as Gram-positive bacteria, *Escherichia coli* (AUMC No. B-53), *Pseudomonas aeruginosa* (AUMC No. B-73), and *Serratia marscescens* (AUMC No. B-55) as Gram-negative bacteria) by disc diffusion assay. It possessed high antibacterial potential towards *E. coli* (Inhibition zone diameter (IZD): 25.1 ± 0.60 mm, MIC value: 3.7 ± 0.08 µg/mL), *B. cereus* (Inhibition zone diameter (IZD): 23.0 ± 0.36 mm, MIC value: 2.5 ± 0.09 µg/mL), and *S. aureus* (Inhibition zone diameter (IZD): 17.4 ± 0.09 mm, MIC value: 3.1 ± 0.11 µg/mL) compared to ciprofloxacin used as antibacterial standard (Inhibition zone diameter (IZD): 15.3 ± 0.07 mm, MIC value: 3.4 ± 0.32 µg/mL for *S. aureus*, Inhibition zone diameter (IZD): 21.2 ± 0.51 mm, MIC value: 2.9 ± 0.20 µg/mL for *B. cereus*, Inhibition zone diameter (IZD): 25.6 ± 0.22 mm, MIC value: 3.9 ± 0.06 µg/mL for *E. coli*) [125].

The new compounds were evaluated for their antibacterial activities against five terrestrial pathogenic bacteria, including *S. aureus* (ATCC 27154), *Staphylococcus albus* (ATCC 8799), *B. cereus* (ATCC 11778), *Escherichia coli* (ATCC 25922), and *Micrococcus luteus* (ATCC 10240) by the microplate assay method. The result showed that Compounds 392–393 showed moderate antibacterial activities against *Staphylococcus aureus* with the MIC values of 25.0 µg/mL and 12.5 µg/mL, respectively. Ciprofloxacin was used as positive control with the MIC value of 0.39 µg/mL [128].

The MIC of compound 395 against *Staphylococcus aureus* (MSSA), Methicillin resistant *Staphylococcus aureus* (MRSA) and *Klebsiella pneumoniae carbapenemase-producing* (KPC) was performed. Vochysiamide B 395 displayed considerable antibacterial activity against the Gram-negative bacterium *Klebsiella pneumoniae* (KPC), a producer of carbapenemases, MIC of 80 µg/mL in comparison with positive controls meropenem and gentamicin with MIC values of 45 µg/mL and 410 µg/mL against KPC [129].

The antimicrobial activities of compounds were tested against six microorganisms by the microdilution method, including *Mycobacterium phlei*, *Bacillus subtilis*, *Vibrio parahemolyticus*, *Escherichia coli*, *Pseudomonas aeruginosa*, and *Proteus vulgaris*. Among them, compound 416 showed promising activity against *M. phlei* with the same MIC values as positive control ciprofloxacin of 12.5 µM, which indicated the antituberculosis potential. Compound 415 showed activities against *B. subtilis* with MIC value of 100 µM. Compound 416 showed activities against *M. phlei* with MIC value of 6.25 µM. Ciprofloxacin was positive control shared same MIC values of 1.56 µM against *Mycobacterium phlei* and *Bacillus subtilis* [135].
Compound 418 was tested for antimicrobial activities against two human pathogens (E. coli and S. aureus), seven aquatic bacteria (Aeromonas hydrophila, Edwardsiella tarda, Micrococcus luteus, Pseudomonas aeruginosa, Vibrio alginolyticus, Vibrio harveyi, and Vibrio parahaemolyticus). Compound 418 exhibited inhibitory activity against E. coli, and S. aureus with same MIC values of 32 µg/mL. Positive control was chloramphenicol which with MIC values of 2 µg/mL and 1 µg/mL against E. coli, and S. aureus [136].

Antibacterial activity was evaluated against S. aureus and methicillin-resistant S. aureus. Simplicidine K 430 exhibited antibacterial activity against Staphylococcus aureus and methicillin-resistant S. aureus with equal MIC values of 128 µg/mL. Vancomycin was used as a positive control for antibacterial activity and displayed equal MIC values of 0.5 µg/mL against both S. aureus and methicillin-resistant S. aureus [96].

3.1.3. Antiviral Activity

Anti-enterovirus 71 (EV71) was assayed on Vero cells with the CCK-8 (DOjinDo, Kumamoto, Japan) method. The 50% inhibitory concentration (IC50) of the testing compound was calculated using the GraphPad Prism software. Ribavirin was used as the positive control with an IC50 value of 177.0 µM. Vaccinio J 125 exhibited in vitro anti-EV71 with IC50 value of 30.7 µM, and the inhibition effect was stronger than positive control ribavirin [44].

Anti-HIV activities of compound 150 was tested in vitro by HIV-I virus-transfected 293 T cells. At the concentration of 20 µM, 150 showed a weak inhibitory rate of 16.48 ± 6.67%. Efavirenz was used as the positive control, with an inhibitory rate of 88.54 ± 0.45% at the same concentration [47].

3.2. Cytotoxic Activity or Anticancer

Nectrianolins A–C 11, 12, and 13 were evaluated for their in vitro cytotoxicity against HL60 (human leukemia 60) and HeLa cell lines by the MTT method using a published protocol. Compounds 11, 12, and 13 exhibited cytotoxic activity against the HL60 cell line with IC50 values of 1.7 µM, 1.5 µM and 10.1 µM, respectively. Additionally, compounds 11, 12, and 13 exhibited cytotoxicity against the HeLa cell line with IC50 values of 34.7 µM, 16.6 µM and 52.1 µM, respectively [13].

Compounds 29 and 236 were evaluated for their cytotoxic activities against three human tumor cell lines HeLa, HCT116 (Human colon cancer tumor cells), and A549 (Human lung cancer cells), both of them exhibited weak to moderate cytotoxic activities with IC50 values ranging from 21.09 to 55.43 µM (29: 58.75 ± 1.77 µM, 47.75 ± 1.68 µM, 29.58 ± 1.47 µM, 236: 21.18 ± 1.33 µM, 21.04 ± 1.32 µM, 37.33 ± 1.57 µM against HeLa, HCT116 and A549 respectively) [19].

The cytotoxic activity of the isolated compounds 78–79 and 113–114 were tested against Hela cells. Compound 79 showed weak cytotoxic activities against Hela cells with IC50 value of 43.7 ± 0.43 µM. Compound 78 did not show significant cytotoxic activity. As the oxoindoloditerpene epimers, the 3α-epimer 79 was clearly more cytotoxic than the 3β-epimer 78, suggesting that their cytotoxic activity depended on their stereochemistry. The acetoxy derivatives 113 and 114 showed weak cytotoxic activities against Hela cells with IC50 values of 83.8 ± 5.2 µM and 53.5 ± 2.1 µM respectively [35].

Since many triterpenoids isolated from plants of the family Schisandraceae are reported to reduce the risk of liver diseases and cancer, compounds 93–100 were evaluated for in vitro cytotoxicity against human hepatocellular liver carcinoma cell (HepG2), according to the MTT method, with cisplatin as the positive control (IC50 value of 9.8 ± 0.21 µM). Compounds 93–100 showed moderate cytotoxic activity with IC50 values ranging from 14.3 to 21.3 µM (IC50 values of compounds 93: 15.6 µM, 94: 16.1 µM, 95: 16.4 µM, 96: 15.4 µM, 97: 17.9 µM, 98: 18.8 µM, 99: 14.3 µM, 100: 21.3 µM). It should be noted that those metabolites 93–100 produced during fermentation showed stronger cytotoxicity to HepG2 cell line than that of nigranoic acid, the main component of non-fermented K. angustifolia [39].
The in vitro cytotoxicity of compound 119 against the human acute monocytic leukemia cell line (THP-1) was evaluated using a resazurin-based assay and an ATP-lite assay. Compound 119 demonstrated marked cytotoxicity against the human acute monocytic leukemia cell line (THP-1) with an IC<sub>50</sub> value of 8.0 µM [42].

The in vitro cytotoxicity assay was performed with some cancer cells including the mouse fibroblast cell line L929, cervix carcinoma cell line KB-3-1, human breast adenocarcinoma MCF-7, human prostate cancer PC-3, squamous carcinoma A431, human lung carcinoma A549 and ovarian carcinoma SKOV-3. Compounds 169, 170 showed significant cytotoxicity against the mouse fibroblast cell line L929 and the cervix carcinoma cell line KB-3-1, with IC<sub>50</sub> values ranging from 6.3 to 23 µg/mL (169: 23 µg/mL against the mouse fibroblast cell line L929, 22 µg/mL against cervix carcinoma cell line KB-3-1 170: 6.3 µg/mL against the mouse fibroblast cell line L929, 11 µg/mL against cervix carcinoma cell line KB-3-1). Compound 170 showed the strongest cytotoxicity among the metabolites tested against human breast adenocarcinoma MCF-7 cells with IC<sub>50</sub> value of 1.5 µg/mL. Besides, compound 170 showed cytotoxicity against squamous carcinoma A431, human lung carcinoma A549 and ovarian carcinoma SKOV-3 with IC<sub>50</sub> values of 6.5 µg/mL, 16 µg/mL and 6.5 µg/mL. Epothilon B was used as positive control (IC<sub>50</sub> values against 7 cancer cells mentioned above were 0. 8 ng/mL, 0. 06 ng/mL, 0.04 µg/mL, 1.1 ng/mL, 0.1 ng/mL, 2 ng/mL and 0.12 ng/mL) [52].

Standard MTT assays employing MDA-MB-435 and A549 cell lines were performed. The IC<sub>50</sub> was determined by a 50% reduction of the absorbance in the control assay. Compound 176 exhibited cytotoxicity against MDA-MB-435 and A549 cell lines with IC<sub>50</sub> values of 16.82 and 20.75 µM, respectively. The positive control was used by Epirubicin (EPI) with IC<sub>50</sub> values of 0.26 and 5.60 µM against MDA-MB-435 and A549 cell lines [54].

All isolated new compounds 190–194 were evaluated for their cytotoxic activities against various cancer cell lines, which include A549, Raji, HepG2, MCF-7, HL-60 and K562. Compounds 190–194 displayed in vitro inhibitory activities against the six tumor cell lines to various degrees. Among them, compound 192 showed the most potent cytotoxicity against all evaluated cell lines with IC<sub>50</sub> values of 1.2, 2.0, 1.6, 2.2, 1.0 and 1.2 µg/mL, respectively, which were even stronger than an anti-tumor agent DDP used as positive control (IC<sub>50</sub> values against six cell lines: 2.8 µg/mL, 2.1 µg/mL, 2.6 µg/mL, 2.4 µg/mL, 2.1 µg/mL and 2.2 µg/mL). Compounds 193 and 194 also exhibited moderate growth inhibition against six tested cell lines with IC<sub>50</sub> values ranging from 6.3–26.8 µg/mL for 193 and IC<sub>50</sub> 3.1–24.4 µg/mL for 194. However, compounds 190 and 191 were effective only against HL-60 and K562 cell lines (IC<sub>50</sub> value: 190: 24.1 µg/mL, 10.7 µg/mL 191: 24.2 µg/mL, 23.1 µg/mL). These results indicated that the keto or hemiketal functionality (e.g., 192–195) would play an important role in cytotoxic activity. Additionally, the activity profile reflected that the hydroxyl-substituted position had a different impact on cytotoxic activity. 2-Pyrones were more active as cytotoxic agents if the alkyl chain at C-6 was oxygenated but the addition of the hydroxyl subunit to C-8 and C-9 significantly decreased the activity [59].

The isolated compound 202 was preliminary evaluated for its cytotoxicities against MCF-7, NCI-H460, HepG-2, and SF-268 cell lines with cisplatin as the positive control. The new compound 202 exhibited weak growth inhibitory activity against the tumor cell lines MCF-7 and HepG-2 with IC<sub>50</sub> values of 70 and 60 µM, respectively [64].

Cytotoxic activities of compound 209 against HeLa, MCF-7 and A549 cell lines were evaluated by the MTT method. Adriamycin was used as a positive control. The results showed that 209 displayed cytotoxic activity against A549 cell lines with IC<sub>50</sub> value of 15.7 µg/mL [66].

Compound 221 was assessed for its antiproliferative activities against the mouse lymphoma (L5178Y) cell line using the in vitro cytotoxicity (MTT) assay and kahalalide F as a standard antiproliferative agent (IC<sub>50</sub> = 4.30 µM). Results revealed the new compound, aflaquinolone H (221), exhibited moderate antiproliferative activity (IC<sub>50</sub> = 10.3 µM) which highlights the role of the hydroxyl group at C-21 for the antiproliferative activity [71].
Compounds 222–223 were evaluated for in vitro inhibition of cell proliferation by the MTT method using a panel of four human cancer cell lines: NCI-H460 (non-small cell lung cancer), SF-268 (CNS glioma), MCF-7 (breast cancer), and PC-3 (prostate adenocarcinoma) cells. Compounds 222 and 223 showed moderate cytotoxicity against four human cancer cell lines with IC\(_{50}\) values ranging from 12.0 to 28.3 µM (IC\(_{50}\) values against K562, SW480, and HepG2 cells: 262: 15.9 (13.1–19.3) µM, 12.0 (8.8–16.4) µM, 28.3 (23.2–34.6) µM 427: 20.6 (14.0–30.3) µM, 20.3 (16.8–24.4) µM, 20.4 (16.4–25.4) µM). In addition, compound 426 showed moderate cytotoxicity towards K562 cells with an IC\(_{50}\) value of 18.7 µg/mL. Cisplatin was used as the positive control with IC\(_{50}\) value of 1.3 µg/mL. Doxorubicin (Adriamycin) was used as positive control for its cytotoxicity against four human cancer cell lines: NCI-H460, HeLa human cervical cancer cells, HCT116 (human colon cancer cells), HepG2 human hepatocellular carcinoma cells, A549 (human lung cancer cells), and MCF7 (human breast cancer cells). Compound 241 showed weak cytotoxic effects against HepG2 cells with IC\(_{50}\) value of 97.4 µM, while the positive control cisplatin showed IC\(_{50}\) value of 21.1 µM.

The cytotoxicity of compound 244 against a human cervical tumor cell line (HeLa) was tested using the MTT assay. Compound 244 presented an IC\(_{50}\) value of 100 µmol/L. Camptothecin was used as positive control and presented an IC\(_{50}\) of 0.12 µmol/L.

The cytotoxicities against HBE, THLE, and MDA-MB-231 of compound 252 were evaluated by MTT method. 252 showed selective cytotoxicities against MDA-MB-231 with IC\(_{50}\) of 24.6 ± 1.3 µg/mL.

Compounds 262, 426–427 were evaluated for their cytotoxicity against a human leukemia cell line (K562), a colon adenocarcinoma cell line (SW480), and a human liver carcinoma cell line (HepG2). Compounds 262 and 427 showed moderate cytotoxic activity against all the tested cell lines with IC\(_{50}\) ranging from 12.0 to 28.3 µM (IC\(_{50}\) values against K562, SW480, and HepG2 cells: 262: 15.9 (13.1–19.3) µM, 12.0 (8.8–16.4) µM, 28.3 (23.2–34.6) µM 427: 20.6 (14.0–30.3) µM, 20.3 (16.8–24.4) µM, 20.4 (16.4–25.4) µM). In addition, compound 426 showed moderate cytotoxicity towards K562 cells with an IC\(_{50}\) value of 18.7 µg/mL. Cisplatin was used as the positive control with IC\(_{50}\) values of 3.8, 5.5, and 6.8 µM toward K562, SW480, and HepG2 cells, respectively.

Compound 281 was evaluated for cytotoxic activities against three cancer cell lines HCT 116, HeLa, and MCF7, and displayed strong biological effect against MCF7 with halmaximal inhibitory concentration (IC\(_{50}\)) value at 7.73 ± 0.11 µM compared with the cis-platinum (14.32 ± 1.01 µM).

The isolated compound 287 was examined for cytotoxicity by MTT assay. Camptothecin was used as positive control for HL60 with IC\(_{50}\) = 23.6 nM. 287 exhibited cytotoxicity against human promyelocytic leukemia HL60 cells with IC\(_{50}\) value of 1.33 µM. The higher cytotoxicity of 287 and E (Figure 13) compared to that of the related compounds F (Figure 13) and G (Figure 13) was attributed to their increased cell membrane permeability due to the presence of the hydroxyl group.

Compound 288 was investigated for its cytotoxicities against SMMC-7721 cell by MTT method. The results showed that 288 inhibited SMMC-7721 cells proliferation in a dose-dependent manner (100 µM, 50 µM, 25 µM, 12.5 µM, 6.25 µM), with IC\(_{50}\) of 61 ± 2.2 µM.

The cytotoxicities of compound 297 were tested by using human promyelocytic leukemia HL-60, human hepatoma SMMC-7721, non-small cell lung cancer A-549, breast cancer MCF-7 and human colorectal carcinoma SW480 cell lines, 297 showed cytotoxicity against MCF-7 with the ratio of inhibition at 72% for a concentration at 40 µM (IC\(_{50}\) of positive control Taxol < 0.008 µM).

The cytotoxicities of compound 311 were evaluated against the A549 and HepG2 cell lines by the MTT method. Newly isolated compound 311 showed weak activities with IC\(_{50}\) values of 11.05 µM and 19.15 µM, respectively, against the tested cell lines. Doxorubicin was used as a reference (0.94 µM and 1.16 µM).

The obtained compound 320 was evaluated for its cytotoxic activities against A549 human lung cancer cells and HepG2 human liver cancer cells. Compound 320 exhibited
potent cytotoxic activities towards A549 human lung cancer cells and HepG2 human liver cancer cells with IC\textsubscript{50} values of 23.73 ± 3.61 µM and 35.73 ± 2.15 µM, respectively [90].

The anti-tumor activities of compounds 336–337 were evaluated against Ramos and H1975 cell lines. 337 displayed the most promising anti-tumor activity against both Ramos and H1975 cell lines with IC\textsubscript{50} values of 0.018 µM and 0.252 µM, respectively. Compound 337 may be more effective in anti-tumor activity against Ramos and H1975 than stand drug Ibrutinib and afatinib, with IC\textsubscript{50} values of 28.7 µM and 1.97 µM. These findings suggest that compound 337 might be promising lead for leukemia and lung cancer treatments. In addition, 336 also displayed anti-tumor activity against both Ramos and H1975 cell lines with IC\textsubscript{50} values of 17.98 and 7.3 µM, respectively [113].

Compound 343 was evaluated for the cytotoxicities against three human tumor cell lines, including a human breast cancer cell line (MDA-MB-435), a human gastric cancer cell line (SGC-7901), and a human lung adenocarcinoma epithelial cell line (A549) by MTT method. It is notable that penochalasin K 343 exhibited remarkable broad-spectrum inhibitory activities against all the tested cell lines (IC\textsubscript{50} values against MDA-MB-435, SGC-7901 and A549: 4.65 ± 0.45 µM, 5.32 ± 0.58 µM and 8.73 ± 0.62 µM). Epirubicin was used as a positive control with IC\textsubscript{50} values of 0.56 ± 0.06 µM, 0.37 ± 0.11 µM and 0.61 ± 0.05 µM against MDA-MB-435, SGC-7901 and A549 [114].

The cytotoxicity was evaluated by the [3H] thymidine assay using breast cancer (MCF-7) and colon cancer (COLO-205) cell lines. Doxorubicin (10 µg), was used as a positive control with ED\textsubscript{50} (50% effective dose) value of 1.8 µg/mL against MCF-7 cell line. Compound 362 showed cytotoxic activity against MCF-7 cell line with ED\textsubscript{50} value of >10 µg/mL [116].

Compound 363 was evaluated for its cytotoxicity against different cancer cell lines MOLT-4, A549, MDA-MB-231 and MIA PaCa-2 by MTT assay. Interestingly, compound 363 showed considerable cytotoxic potential against the human leukaemia cancer cell line (MOLT-4) with IC\textsubscript{50} value of 20 µmol/L, it was not as active as the positive control flavopiridol (IC\textsubscript{50} value of 0.2 µmol/L) [117].

Cytotoxicity against four tumor cell lines (A549, HeLa, MCF-7, and THP-1) of compound 365 was evaluated. In the cytotoxic assay, compound 365 displayed weak in vitro cytotoxicity against the THP-1 cell line, with IC\textsubscript{50} value of 40.2 µM [118].

The cytotoxic effect of 389 was evaluated in vitro towards ovarian (SK-OV-3), epidermoid (KB), malignant melanoma (SK-MEL), human breast adenocarcinoma (MCF-7), colorectal adenocarcinoma (HCT-116), and ductal (BT-549) carcinomas. Doxorubicin (positive control) and DMSO (negative control) were used. It had selective and potent effect against BT-549, MCF-7, SKOV-3, and HCT-116 cell lines with IC\textsubscript{50} values of 0.09 ± 0.05, 21 ± 0.07, 1.23 ± 0.03, and 0.59 ± 0.01 µM, respectively, compared to doxorubicin (IC\textsubscript{50} value of 0.045 ± 0.11, 0.05 ± 0.01, 0.321 ± 0.21, and 0.24 ± 0.04 µM, respectively). Fusarthioamide B (389) may provide a lead molecule for future developing of antitumor and antimicrobial agents [125].

In the cancer cell line cytotoxicity assays, compound 395 displayed low activity against human non-small cell lung A549 and human prostate PC3 cell lines (A549: EC\textsubscript{50} (concentration for 50% of maximal effect) = 86.4 µM for 395, PC3: EC\textsubscript{50} = 40.25 µM for 395). 1.5 mM hydrogen peroxide was used as positive control (100% dead cells), 0.1% dimethyl sulfoxide was used as negative control (100% live cells) [129].

Compounds 396–397 were evaluated for their cytotoxic activity against four human tumor cell lines (SF-268, MCF-7, HepG-2 and A549) by the SRB (Sulforhodamine B) method. As a result, compounds 396, 397 showed weak inhibitory activities against the four tumor cell lines with IC\textsubscript{50} values ranging from 30 to 100 µM (IC\textsubscript{50} values against SF-268, MCF-7, HepG-2 and A549 396: 41.68 ± 0.88 µM, 37.68 ± 0.3 µM, 48.33 ± 0.1 µM and 53.36 ± 0.91 µM, 397: 69.46 ± 7.08 µM, 97.71 ± 0.72 µM, 79.43 ± 0.63 µM and 0 ≥ 100 µM). Cisplatin was used as a positive control with IC\textsubscript{50} values of 3.39 ± 0.29 µM, 3.19 ± 0.12 µM, 2.42 ± 0.14 µM and 1.56 ± 0.08 µM against the four human tumor cell lines [41].

The in vitro cytotoxicity assay was performed according to the MTS method in 96-well microplates. Five human tumor cell lines were used: human myeloid leukemia HL-60,
human hepatocellular carcinoma SMMC-7721, lung cancer A-549, breast cancer MCF-7, and human colon cancer SW480, which were obtained from ATCC (Manassas, VA, USA). Cisplatin was used as the positive control for the cancer cell lines (IC<sub>50</sub> values against HL-60, A-549, SMMC-7721, MCF-7, and SW480 cell: 4.05 ± 0.11, 19.40 ± 0.71, 14.91 ± 0.36, 22.96 ± 0.58 and 23.15 ± 0.22 µM). Compound 447 demonstrated moderate cytotoxicity against HL-60, A-549, SMMC-7721, MCF-7, and SW480 cell with IC<sub>50</sub> values of 15.80, 15.93, 19.42, 19.22, and 23.03 µM, respectively [27].

3.3. Other Activities

α-Glucosidase inhibitors are helpful to prevent deterioration of type 2 diabetes and for the treatment of the disease in the early stage, so the α-glucosidase inhibitory effects of the isolated compounds were evaluated. As a result, compounds 247, 248 exhibited potent α-glucosidase inhibitory activity with IC<sub>50</sub> values of 25.8 µM, 54.6 µM, respectively, which were much better than acarbose (IC<sub>50</sub> 703.8 µM) as a positive control. Compounds 7 and 249 showed moderate inhibitory activity against α-glucosidase with IC<sub>50</sub> values of 188.7 µM and 178.5 µM, respectively. The results indicated that the configuration at C-5 in compounds 6 and 7 might affect α-glucosidase inhibitory activity. Moreover, the methoxy group at C-15 in the lasiodipolid derivatives decreased the activity (248 vs. H (Figure 13)). For compounds 247, I (Figure 13), J (Figure 13), and K (Figure 13), compounds 247 and I showed potent α-glucosidase inhibitory effects, whereas J and K were inactive, which attested that the position of the hydroxy group had a significant impact on the activity [10].

AChE inhibitory activities of the compound 14 were assayed by the spectrophotometric method. Compound 14 indicated anti-AChE activity with inhibition ratio at 35% in the concentration of 50 µM. Tacrine (Sigma, purity > 99%) was used as a positive control of inhibition ratio at 52.63% with the concentration of 0.333 µM [14].

The inhibition of the marine phytoplankton Chattonella marina, Heterosigma akashiwo, Karlodinium veneficum, and Prorocentrum donghaiense by 31–37 were assayed. The results showed that 32–34 were more active to C. marina, K. veneficum, and P. donghaiense than 31 and 35–37 (IC<sub>50</sub> against C. Marina, H. akashiwo, K. veneficum and P. donghaiense: 31: 11, 4.6, 12 and 23 µg/mL, 32: 1.2, 4.3, 1.3 and 5.7 µg/mL, 33: 3.3, 9.2, 1.5 and 6.8 µg/mL, 34: 0.93, 7.8, 2.7 and 4.9 µg/mL, 35: 6.7, 2.9, 6.6 and 10 µg/mL, 36: 5.4, 5.8, 8.4 and 14 µg/mL, 37: 3.7, 6.9, 9.4 and 12 µg/mL). A structure-activity relationship analysis revealed that the phenyl group in 32–34 may contribute to their inhibitory ability, but the isomerization at C-9 and/or C-11 of 32–34 only has slight influences on their activities. K2Cr2O7 was used as positive control with IC<sub>50</sub> values of 0.46, 0.98, 0.89 and 1.9 µg/mL, respectively [21].

The biological effects of compound 38 were evaluated on the seedling growth of Arabidopsis thaliana, and 38 displayed an effect on the root growth but no remarkable inhibition of leaf growth in Arabidopsis thaliana [22].

The antioxidant activity was estimated by using adapted 2, 2′-diphenyl-b-picrylhydrazyl (DPPH) method. Ascorbic acid (IC<sub>50</sub> = 2.0 µM) and methanol were used as positive and negative controls, respectively. 49 and 413 showed remarkable antioxidant activity with IC<sub>50</sub> values of 2.50 and 5.75 µM respectively [24].

The biological activity properties of compounds 63–65 were evaluated for inhibitory activity against pancreatic lipase. Compounds 63–65 displayed potent inhibition in the assay with IC<sub>50</sub> values of 2.83 ± 0.52, 5.45 ± 0.69, and 6.63 ± 0.89 µM, respectively, compared to the standard kaempferol (1.50 ± 0.21 µM) [29].

Nuclear transcription factor (PXR) can regulate a suite of genes involved in the metabolism, transport, and elimination of their substances, such as CYP3A4 and MRP, therefore, it is regarded as an important target to treat cholestatic liver disorders. So compound 76 was assayed for agonistic effects on PXR. Compound 76 displayed the significant agonistic effect on PXR with EC<sub>50</sub> value of 134.91 ± 2.01 nM [33].

Brine shrimp inhibiting assay was assayed. Compound 80 displayed brine shrimp inhibiting activities with IC<sub>50</sub> value of 10.1 µmol/mL. The SDS (sodium dodecyl sulfate)
was employed as positive control and its inhibiting ratio was 95% for brine shrimp and LC₅₀ 0.6 µmol/mL [36].

Monitoring the NO level in LPS-activated cells has become a common approach for evaluating the potential anti-inflammatory activities of compounds. Isolates 82–92 were evaluated for their inhibitory activity against NO production in LPS-activated RAW 264.7 macrophages, while indomethacin was used as a positive control. Compounds 89–91 exhibited inhibitory effects with IC₅₀ values of 21, 24 and 16 µM, respectively, which are lower than that of the positive control indomethacin (IC₅₀ = 38 ± 1 µM), while compound 85 exhibited moderate inhibition with an IC₅₀ value of 42 µM. Preliminary structure–activity relationships revealed that the analogues with the S absolute configureuration at C-18 (e.g., 89–91) significantly enhanced the activity, as exemplified by compound 89 showing inhibition against NO production in RAW 264.7 macrophage cells with an IC₅₀ value of 21 µM, whereas compound 87 exerted less than 40% inhibition at 50 µM. In addition, all isolated compounds (82–92) were tested for their inhibitory activity of Mycobacterium tuberculosis protein tyrosine phosphatase B (MptpB). Compound 89 displayed inhibition with an IC₅₀ value of 19 µM, comparable to the positive control (oleanolic acid, IC₅₀ = 22 ± 1 µM). Compounds 83, 85, 86 and 90 showed moderate inhibitory activity of MptpB with IC₅₀ values of 39 ± 2 µM, 42 ± 3 µM, 28 ± 1 µM and 35 ± 1 µM, respectively [38].

Compounds 135–146 were evaluated for their inhibitory effects on the NO production in LPS-stimulated RAW264.7 microglial cells using Griess assay. Meanwhile, the effects of compounds 135–146 on cell proliferation/viability were measured using the MTT method. As a result, compounds 138, 139, 142, 143, 145 and 146 exhibited inhibitory activity against NO production with IC₅₀ values in the range of 56.3–98.4 µM (IC₅₀ values of compounds on LPS-stimulated NO production in RAW264.7 macrophage cells 138: 85.2 ± 4.3 µM, 139: 98.4 ± 5.6 µM, 142: 95.9 ± 3.4 µM, 143: 64.8 ± 1.3 µM, 145: 60.0 ± 3.1 µM, 146: 56.3 ± 1.1 µM). Indomethacin was used as a positive control (IC₅₀ = 33.6 ± 1.4 µM) [45].

Measurement of ATP release of thrombin-activated platelets of the isolated compound 168 was investigated by applying D. S. Kim’s method. Compound 168 exhibited inhibitory activities on ATP release of thrombin-activated platelets with IC₅₀ value of 57.6 ± 3.2 µM. Staurosporine served as the positive control with IC₅₀ value of 3.2 ± 0.6 µM [51].

The inhibition of biofilm formation against Staphylococcus aureus DSM 1104 was tested in 96-well tissue microtiter plates. The compounds were tested in concentrations of up to 256 µg/mL. MeOH and cytochalasin B were used as negative and positive control, respectively. Minimum Inhibitory Concentration (MIC) value of 256 µg/mL was observed for metabolite 169 and it showed a weak inhibition of biofilm formation of 20.78% at 256 µg/mL [52].

A colorimetric α-glucosidase (Sigma-Aldrich Co. CAS number: 9001-42-7, E.C 3.2.1.20) assay of compounds 176–180 was performed. 1-deoxynojirimycin (St. Louis, MO, USA) was used as a positive control. In addition, The DPPH radical scavenging assay of these compounds was also conducted with 96-well plates using a revised method. The positive control was used by Vitamin C. Compounds 176–178 showed significant α-glucosidase inhibitory activity with IC₅₀ values of 35.8 µM, 53.3 µM and 60.2 µM, respectively, compared to 62.8 µM for the positive control (1-deoxynojirimycin). Moreover, compound 179 exhibited radical scavenging activity against DPPH with EC₅₀ value of 68.1 µM, the EC₅₀ value of positive control ascorbic acid was 22.3 µM [54].

The tested compounds 200, 276, 344–346 were investigated for their capacity to inhibit biofilm formation in the reference strains of S. aureus, E. faecalis and E. coli. Acetylquestinol 276, 345 and 200 were found to cause a significant reduction inbiofilm production by E. coli ATCC 25922 with the percentage of biofilm formation: 50.6 ± 17.6%, 23.7 ± 24.8% and 57.6 ± 8.1%, respectively. On the other hand, emodin 344 and 345 showed inhibition of biofilm production in S. aureus ATCC 25923 (21.1 ± 11.5% and 21.8 ± 18.9%). Interestingly, 345, which is the most effective in inhibiting biofilm formation in E. coli ATCC 25922, also caused nearly 80% reduction of the biofilm production in S. aureus ATCC 25923 [62].
Compound 207 was evaluated for its acetylcholinesterase (AChE) inhibitory activity using the Ellman colorimetric method, it showed weak AChE inhibitory activity with the inhibition ratio of 11.9% at the concentration of 50 µmol/mL [65].

The anti-inflammatory activities of the isolated compounds 210–211 were evaluated by measuring the inhibitory activity of nitric oxide (NO) production levels in the lipopolysaccharide (LPS)-induced RAW264.7 macrophage cells. 210–211 exhibited moderate inhibitory activities on NO production in LPS-stimulated RAW264.7 cells without cell cytotoxicities [67].

The transformed products 224–225 and the parent compound L (Figure 13) were evaluated for the neuroprotective activity using the LPS-induced neuro-inflammation injury assay. 224–225 exhibited moderate neuroprotective activity by increasing the viability of U251 cell lines with EC50 values of 35.3 ± 0.9 nM and 32.1 ± 0.9 nM, respectively, while L (EC50 = 8.3 ± 0.4 nM) exhibited comparable activity with the positive control ibuprofen (EC50 = 19.4 ± 0.7 nM). The transformed products 224–225 and L all exhibited considerable neuroprotective activity in the invitro LPS-induced neuro-inflammation injury assay, suggesting that the hupA moiety shared by these compounds may be used as a lead structure for the development of neuroprotective drugs [73].

The artificial insect mixed drug method was used to determine the insecticidal activities of compound 228. Compound 228 displayed remarkable insecticidal activities against first instar larvae of the cotton bollworm Helicoverpa armigera with mortality rates of 70.2%. Commercially-available matrine was used as positive control, causing 87.4% mortality rate under the same conditions. Acute cytotoxicity towards hatching rate, malformation and mortality of zebrafish embryos or larvae were also performed. Compounds 227 and 228 significantly decreased the hatching rate of zebrafish embryos, compound 228, used at concentrations of 5–100 µg/L, decreased the hatching rate of zebrafish embryos to below 20% [74].

The potential phytotoxicity of 246 against lettuce seedlings (Lactuca sativa L.) was studied. Aqueous solutions of 246 ranging between 25 and 200 µg mL⁻¹, were assayed for its effects on seed germination, root length, and shoot length of the lettuce. Compound 246 showed the most robust inhibitory effect on root growth. Compound 246 inhibited root growth by 50% at a concentration of 25 µg/mL. In addition, the highest concentration of 246 (200 µg/mL) strongly exerted an inhibitory effect on seed germination (90% inhibition) [81].

Compounds 256–257 were investigated for their inhibitory activities against the LPS-activated production of NO in RAW264.7 cells using the Griess assay with indomethacin as a positive control (IC50 = 37.5 ± 1.6 µM). The effects of compounds on cell proliferation/viability were determined using MTT method, and none of the test compounds exhibited cytotoxicity at their effective concentrations. Compounds 256 and 257 showed strong inhibitory effects on the production of NO, with IC50 values of 0.78 ± 0.06 and 1.26 ± 0.11 µM, respectively [84].

In vitro anti-inflammatory effects of compounds 258–261 were evaluated in lipopolysaccharide (LPS)-stimulated RAW264.7 macrophages. 258–261 exhibited excellent inhibitory effects on the production of interleukin-1β (IL-1β), tumor necrosis factor-α (TNF-α), and nitric oxide (NO) in LPS-induced macrophages with the IC50 values ranging from 16.21 ± 1.62 µM to 35.23 ± 3.32 µM, from 19.83 ± 1.82 µM to 42.57 ± 4.56 µM, from 16.78 ± 1.65 µM to 38.15 ± 3.67 µM, respectively, similar with the positive control indomethacin. Those results indicated that, terrusnolides A–D (258–261) might play a significant role as a lead compound in the study of anti-inflammatory agents. In addition, compounds 258–261 were also investigated for the inhibitory activities against BACE1 by M-2420 method and acetylcholinesterase (AchE) using Ellman’s method. Compound 260 exhibited weak AchE inhibitory activity with IC50 value of 32.56 ± 3.16 µM, compound 261 exhibited weak BACE1 inhibitory activity with IC50 value of 34.75 ± 4.56 µM. LY2811376 and Donepezil were used as the positive control in BACE1 and AchE inhibitory assay with IC50 values of 0.25 ± 0.04 µM and 0.05 ± 0.01 µM, respectively [85].

The Indoleamine 2,3-dioxygenase (IDO) inhibitory activity assay of compounds 284–286 were carried out. The results showed that compound 285 possessed significant
inhibitory activity against IDO with IC\textsubscript{50} value of 0.11 μM. Epacadostat, as the positive control, was one of the most potent IDO inhibitors with IC\textsubscript{50} value of 0.05 μM. For compounds 284 and 286, they showed relatively strong inhibitory activity with IC\textsubscript{50} values of 1.47 μM and 6.36 μM, respectively [92].

NF-κB has been considered as an attractive therapeutic target for the cancer research. Compound 288 was investigated for its effects on NF-κB pathway by reporter gene assay. The results showed that it could activate the NF-κB pathway with increments in the relative luciferase activity at a concentration of 50 μM [93].

The phytotoxic activities of 295 and 296 were investigated by seed germination test on lettuce (Lactuca sativa L.) with 2,4-dichlorophenoxyacetic acid (0.3 μg/mL) as the positive control. Compounds 295 and 296 each inhibited the growth of both roots and hypocotyls at 30 μg/mL. Furthermore, 295 suppressed seed germination at 100 μg/mL [97].

Acetylcholinesterase (AChE) inhibitory activities of the compound 302 were assayed by the spectrophotometric method developed by Ellman with modification. 302 showed weak AChE inhibitory activity (The percentage inhibition was at 20%~60% in 50 μM) [99].

The 5-lipoxygenase (5-LOX) inhibitory potential of 306–308 from Fusarium sp. was assessed in an attempt to explore their activity against 5-LOX. It is noteworthy that 306 displayed prominent 5-LOX inhibitory activity with IC\textsubscript{50} value of 3.61 μM, compared to that of indomethacin (IC\textsubscript{50} = 1.17 μM), while 307 and 308 had moderate activity with IC\textsubscript{50} values of 7.01 μM and 4.79 μM, respectively [101].

α-Glucosidase inhibitory activity was performed in the 96-well plates and acarbose was used as the positive compound. In the inhibitory assay against α-glucosidase, compound 313 displayed moderate activities [104].

The anti-inflammatory activities of selected isolated 4 compounds 314–317 were evaluated as inhibitory activities against lipopolysaccharide (LPS) induced nitric oxide (NO) production in RAW264.7 cell lines. Compound 317 showed the most NO inhibitory effects, with the inhibition of 17.4% NO production in LPS stimulated RAW264.7 cells at 10 μM. At the same concentration, compound 315 significantly inhibited the NO production, with 11.2% inhibitory rate. Compound 314 showed weak NO inhibitory effects at 10 μM, with inhibitory rates of 6.5%. At the same concentration, quercetin, the positive control, inhibited NO production to 12.9% [105].

The Superoxide anion radical scavenging activity of compound 331 was investigated. It displayed strong antioxidant activity with EC\textsubscript{50} value of 1.08 mg/mL on superoxide anion radicals. Ascorbic acid (Vc) was used as positive control with EC\textsubscript{50} value of 0.33 mg/mL [111].

Compounds 333 and 334 were subjected to motility inhibitory and zoosporicidal activity tests against P. capsici (Phomopsis capsici). Compounds 333 and 334 showed more than 50% motility inhibitory activity (IC\textsubscript{50}) at a concentration of 50–100 μg/mL [112].

Human carboxylesterases (hCE 1 and hCE 2) are the important enzymes that hydrolyze chemicals with functional groups, such as a carboxylic acid ester and amide, and they are known to play vital roles in drug metabolism and insecticide detoxication. The isolated compounds 379–385 were assayed for their inhibitory activities against hCE 2. Loperamide was used as a positive control with IC\textsubscript{50} value of 1.31 ± 0.09 μM. Compounds 379, and 383–385 displayed significant inhibitory activities against hCE 2 with IC\textsubscript{50} values of 10.43 ± 0.51, 6.69 ± 0.85, 12.36 ± 1.27, 18.25 ± 1.78 μM, respectively [94].

The inhibitory effects on human carboxylesterases (hCE1, hCE2) of compound 386 were evaluated. The results demonstrated that bysspectin A 386 was a novel and highly selective inhibitor against hCE2 with the IC\textsubscript{50} value of 2.01 μM. Docking simulation also demonstrated that active compound 386 created interaction with the Ser-288 (the catalytic amino-acid in the catalytic cavity) of hCE2 via hydrogen bonding, revealing its highly selective inhibition toward hCE2 [124].

Compounds 392–393 were also evaluated for growth inhibition activity against newly hatched larvae of H. armigera Hubner. Compounds 392 and 393 showed growth inhibition activities against newly hatched larvae of H. armigera Hubner with the IC\textsubscript{50} values of 150 and
100 μg/mL, respectively. Azadirachtin was used as positive control with the IC_{50} value of 25 μg/mL [128].

Antioxidant activity of the compound 403 was determined by DPPH assay and compared with the positive control BHT. Compound 403 showed moderate antioxidant activities with IC_{50} value of 120.1 ± 11.7 μg/mL [131].

The new compounds 406–407 were subjected for determination of the xanthine oxidase (XO) inhibitory activity using microtiter plate based NBT assay. Allopurinol was used as a positive control with IC_{50} value of 0.18 ± 0.02 μg/mL. 406 and 407 showed XO inhibitory activity with IC_{50} values of 2.81 ± 0.71 and 0.41 ± 0.1 μg/mL, respectively. The oxidized form of 406 also showed high XO inhibition with IC_{50} value of 0.35 ± 0.13 μg/mL [133].

Compound 421 was tested for osteoclastic differentiation activity using murine macrophage derived RAW264.7 cells. 421 significantly increased the number of mature osteoclasts at the comparable levels to the positive control of kenpaullone, compared to the negative control (DMSO), suggesting that 421 activated a signaling pathway in osteoclastic differentiation [139].

Phytotoxicity assay against lettuce seedlings of compound 432 was carried out using a published protocol. The new compound (−)-dihydrovertinolide 432 exhibited phytotoxicity against lettuce seedlings at a concentration of 50 mg/L [140].

All new compounds were tested for in vitro anti-inflammatory activities against nitric oxide production in lipopolysaccharide (LPS)-induced RAW264.7 cells, and dexamethasone was used as the positive control. Compound 436 showed significant inhibitory activity against NO production in LPS-induced RAW264.7 cells with an IC_{50} value of 1.9 μM. They were also evaluated for in vitro antidiabetic activities based on the inhibition of alpha-glucosidase, PTP1b, and XO. Compounds 437 and 441 showed moderate inhibitory activities toward XO and PTP1b, respectively, at 10 μM with inhibition rates of 67% and 76% [87].

New compound 447 was tested for acetylcholinesterase (AChE) inhibitory activities using the Ellman method with tacrine as the positive control. The results revealed that compound 447 showed weak AChE inhibitory activity with IC_{50} value of 23.85 ± 0.20 μM. Tacrine are the positive control used to estimate AChE inhibitory activity with IC_{50} value of 0.26 ± 0.02 μM [27].

All information about the new compounds are briefly summarized in the Table 1 below.
Table 1. Brief summary of new compounds.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 1        | C\textsubscript{19}H\textsubscript{26}O\textsubscript{7} | 7 | brown oil | Pestalotiopsis sp. | lichen Cetraria islandica (L.) Ach. | Yunnan Province, China | Inhibit the growth of plant pathogenic fungus (1,5) | [9] |
| 2        | C\textsubscript{21}H\textsubscript{30}O\textsubscript{8} | 8 | | | | | | |
| 3        | C\textsubscript{21}H\textsubscript{30}O\textsubscript{8} | 7 | | | | | | |
| 4        | C\textsubscript{21}H\textsubscript{28}O\textsubscript{8} | 8 | | | | | | |
| 5        | C\textsubscript{19}H\textsubscript{26}O\textsubscript{7} | 7 | | | | | | |
| 6        | C\textsubscript{15}H\textsubscript{20}O\textsubscript{4} | 6 | white powder | Co-culture Strain 307: Trichoderma sp. the stem bark of Clerodendrum inerme Bacterium B2: Acinetobacter johnsonii | From an aquaculture pond | Guangdong Province, China | Show moderate inhibitory activity against α-glucosidase (7) | [10] |
| 7        | C\textsubscript{15}H\textsubscript{20}O\textsubscript{4} | 6 | | | | | | |
| 8        | C\textsubscript{15}H\textsubscript{24}O\textsubscript{2} | 4 | colorless gum | Trichoderma atroviride | bulb of Lycoris radiata | Hubei Province China | Inactive | [11] |
| 9        | C\textsubscript{15}H\textsubscript{26}O\textsubscript{3} | 3 | white amorphous powder | Co-culture Pestalotiopsis sp. fruits of Drepanocarpus lunatus (Fabaceae) Bacillus subtilis | | | Weak antibacterial activities (9) | [12] |
| 10       | C\textsubscript{15}H\textsubscript{26}O\textsubscript{3} | 4 | colorless oil | | | | | |
| 11       | C\textsubscript{22}H\textsubscript{29}O\textsubscript{5} | 7 | colorless crystal | Nectria pseudotrichia 120-1NP | Inner tissue of Gliricidia sepium healthy stem | Yunnan Province, China | Cytotoxicity (11–13) | [13] |
| 12       | C\textsubscript{26}H\textsubscript{38}O\textsubscript{7} | 8 | yellow oil | | | | | |
| 13       | C\textsubscript{15}H\textsubscript{22}O | 3 | yellow oil | | | | | |
| 14       | C\textsubscript{15}H\textsubscript{26}O\textsubscript{3} | 3 | | Co-culture Nigrospora oryzae Irpex lacteus | leaves of Panax notoginseng | Hebei province, China | Anti-AChE activity | [14] |
| 15       | C\textsubscript{15}H\textsubscript{26}O\textsubscript{2} | 3 | white powder | Emericella sp. XL 029 | | | | |
| 16       | C\textsubscript{15}H\textsubscript{26}O\textsubscript{3} | 3 | colorless oil | | | | | |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 17       | C_{19}H_{24}O_{4} | 8                      | colorless oil        |                   |            |                |                     |      |
| 18       | C_{19}H_{25}ClO_{5} | 7                    | colorless crystals   | Trichothecium crotocigenum |            |                | Antiphytopathogenic activity (17–20) | [16] |
| 19       | C_{22}H_{26}O_{5} | 9                      | colorless crystals   |                   |            |                |                     |      |
| 20       |                 |                        |                      |                   |            |                |                     |      |
| 21       | C_{15}H_{22}O_{4} | 5                      | colorless oil        | Trichoderma atroviride S361 | Bark of Cephalotaxus fortunei | Zhejiang province, China | Inactive | [17] |
| 22       |                 |                        |                      |                   |            |                |                     |      |
| 23       |                 |                        |                      |                   |            |                |                     |      |
| 24       | C_{15}H_{20}O_{4} | 6                      | white amorphous powder | Aspergillus sp. xy02 | leaves of mangrove Xylocarpus moluccensis | Trang Province, Thailand | Antibacterial activity (23–24,26,28) | [18] |
| 25       |                 |                        |                      |                   |            |                |                     |      |
| 26       |                 |                        |                      |                   |            |                |                     |      |
| 27       |                 |                        |                      |                   |            |                |                     |      |
| 28       |                 |                        |                      |                   |            |                |                     |      |
| 29       | C_{15}H_{24}O_{3} | 4                      | colorless oil        | Pestalotiopsis adusta | stem bark of medicinal plant Sinopodophyllum hexandrum (Reyle) Ying | Qinling Mountains China | Weak to moderate cytotoxic activity | [19] |
| 30       | C_{15}H_{26}O_{2} | 3                      | colorless oil        | E. proliferatum AF-04 | green Chinese onion | Lanzhou, China |                     | [20] |
| 31       | C_{14}H_{24}O_{3} | 3                      | colorless crystals   |                   |            |                |                     |      |
| 32       |                 |                        |                      |                   |            |                |                     |      |
| 33       | C_{14}H_{20}O_{2} | 5                      | colorless oil        | Trichoderma asperellum A-YMD-9–2 | marine Red alga Gracilaria verrucosa | Yangma Island, Yantai, China | Potent inhibition of several marine phytoplankton species 31–37 | [21] |
| 34       |                 |                        |                      |                   |            |                |                     |      |
| 35       |                 |                        |                      |                   |            |                |                     |      |
| 36       | C_{22}H_{37}NO_{7} | 5                    | colorless oil        |                   |            |                |                     |      |
| 37       |                 |                        |                      |                   |            |                |                     |      |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|-----------|----------------|---------------------|-----|
| 38       | C_{15}H_{24}O_{4}  | 4                      | crystal powder       | *Alternaria oxytropis* | desert plant locoweed *Oxytropis glabra* | Inner Mongolia, China | Displayed an effect on the root growth in *Arabidopsis thaliana* (38) | [22]|
| 39       |                   |                        | colourless oil       |                   |           |                |                     |     |
| 40       | C_{15}H_{22}O_{4}  | 5                      | colourless oil       |                   |           |                |                     |     |
| 41       | C_{15}H_{20}O_{5}  | 4                      | crystal powder       |                   |           |                |                     |     |
| 42       | C_{15}H_{20}O_{3}  | 5                      | colourless oil       |                   |           |                |                     |     |
| 43       | C_{15}H_{20}O_{5}  | 4                      | colourless oil       |                   |           |                |                     |     |
| 44       | C_{15}H_{20}O_{4}  | 3                      | colourless oil       |                   |           |                |                     |     |
| 45       |                   |                        |                      |                   |           |                |                     |     |
| 46       | C_{15}H_{20}O_{3}  | 3                      |                      |                   |           |                |                     |     |
| 47       |                   |                        |                      |                   |           |                |                     |     |
| 48       | C_{15}H_{22}O_{3}  | 5                      | colorless crystal    | *Pleosporales sp. SK7* | mangrove plant *Kandelia candel* | Guangxi Province, China | | [23]|
| 49       | C_{15}H_{22}O_{4}  | 5                      | yellowish needle crystals | *Irpex lacteus* DR10-1 | waterlogging tolerant plant *D. chinense* | Chongqing China | Antioxidant activity Antibacterial activity | [24]|
| 50       | C_{15}H_{16}O_{3}  | 8                      | colorless crystals   |                   |           |                |                     |     |
| 51       | C_{15}H_{16}O_{4}  | 8                      | colorless oil        |                   |           |                |                     |     |
| 52       | C_{15}H_{20}O_{2}  | 5                      | amorphous powder     | *Trichoderma virens QA-8* | fresh inner tissue of the medicinal plant *Artemisia argyi* | Hubei Province, China | Antibacterial (50–52,55) Antifungal activity (50–55) | [25]|
| 53       | C_{15}H_{20}O_{3}  | 5                      | amorphous powder     |                   |           |                |                     |     |
| 54       | C_{15}H_{24}O_{3}  | 4                      | colorless oil        |                   |           |                |                     |     |
| 55       | C_{14}H_{16}O_{4}  | 7                      | amorphous powder     |                   |           |                |                     |     |
| 56       | C_{15}H_{20}O_{2}  | 3                      | colorless needle     | *Alternaria alternate* | leaves of *Psidium littorale* Raddi | Fujian Province, China | | [26]|

**Table 1. Cont.**
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|-----------------|---------------------|------|
| 57       | C_{15}H_{22}O_{3}  | 5                      | colorless oil        | *Epicoccum* sp. YUD17002 & *Armillaria* sp. | rhizomes of the underground portion of *Gastrodia elata* | Yunnan Province, China |                      | [27] |
| 58       | C_{15}H_{24}O_{4}  | 4                      | white amorphous powder |                  |            |                 |                     |      |
| 59       | C_{15}H_{22}O_{2}  | 5                      | sticky and optically active oil | Colletotrichum gloeosporioides | Cameroonian medicinal plant *Trichilia monadelpha* (Meliaceae) | Yaounde, Central region, Cameroon | Show significant inhibitory activity against pancreatic lipase | [28] |
| 60       | C_{15}H_{22}O_{3}  | 5                      | colorless crystals   | *Penicillium purpurogenum* IMM003 | leaf tissue of the medicinal plant *Edgeworthia chrysantha*. | China |                      | [29] |
| 61       | C_{15}H_{24}O_{4}  | 4                      | yellow oil           | *Fusarium oxysporum* ZZP-R1 | coastal plant *Rumex madaio Makino* | Putuo Island (Zhoushan, China) | Moderate antibacterial effect | [30] |
| 62       | C_{29}H_{42}O_{9}  | 9                      | sticky and optically active oil |                  |            |                 |                     |      |
| 63       | C_{17}H_{22}O_{7}  | 7                      | white powder         |                  |            |                 |                     |      |
| 64       | C_{17}H_{20}O_{7}  | 8                      | colorless crystals   | *Penicillium purpurogenum* IMM003 | leaf tissue of the medicinal plant *Edgeworthia chrysantha*. | China |                      | [29] |
| 65       | C_{16}H_{20}O_{6}  | 7                      | colorless crystals   |                  |            |                 |                     |      |
| 66       | C_{16}H_{24}O_{3}  | 4                      | yellow oil           | *Fusarium oxysporum* ZZP-R1 | coastal plant *Rumex madaio Makino* | Putuo Island (Zhoushan, China) | Moderate antibacterial effect | [30] |
| 67       | C_{20}H_{30}O_{6}  | 6                      | colorless oil        | *Nectria pseudotrichia* 120-1NP | healthy stem of *Gliricidia sepium* | Yogyakarta, Indonesia |                      | [31] |
| 68       | C_{28}H_{39}NO_{3} | 10                     | amorphous powder     | *Drechneria* sp. | root of *Panax notoginseng* | Yunnan, China | Display inhibitory effect (69) Weak antimicrobial effects. (68,70,74) | [32] |
| 69       | C_{28}H_{37}NO_{3} | 11                     | colorless oil        |                  |            |                 |                     |      |
| 70       | C_{33}H_{45}NO_{5} | 12                     | amorphous powder     | *Drechneria* sp. | root of *Panax notoginseng* | Yunnan, China | Display inhibitory effect (69) Weak antimicrobial effects. (68,70,74) | [32] |
| 71       | C_{32}H_{43}NO_{7} | 12                     | colorless oil        |                  |            |                 |                     |      |
| 72       | C_{32}H_{43}NO_{7} | 12                     | colorless oil        |                  |            |                 |                     |      |
| 73       | C_{33}H_{45}NO_{7} | 12                     | colorless oil        |                  |            |                 |                     |      |
| 74       | C_{32}H_{33}NO_{5} | 12                     | colorless oil        |                  |            |                 |                     |      |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 75       | C_{32}H_{33}NO_{9} | 17                     | amorphous powder     | Drechmeria sp.    | root of Panax notoginseng | Yunnan province, China | Display the significant agonistic effect on pregnane X receptor (PXR) (76) | [33] |
| 76       | C_{32}H_{41}NO_{6} | 13                     |                      |                   |            |                |                     |      |
| 77       | C_{26}H_{40}O_{5}  | 7                      | colorless oil        | Neosartorya fijischi JS0553 | Plant G. littoralis | Suncheon, Korea |                     | [34] |
| 78       | C_{28}H_{39}NO_{3} | 10                     | Pale yellow oil      | Aspergillus versicolor | fruits of the mangrove Avicennia marina | Red Sea, Egypt | Weak cytotoxic activity (79) | [35] |
| 79       |                    |                        |                      |                   |            |                |                     |      |
| 80       | C_{20}H_{26}O_{4}  | 8                      | colorless crystals   | Xylaralyce sp.    | healthy leaves of Distylium chinense | China | Display brine shrimp inhibiting activity | [36] |
| 81       | C_{20}H_{26}O_{5}  | 8                      | colorless crystals   | Apiospora montagnei | lichen Cladonia sp. |            |                     | [37] |

Terpenoids
Other terpenoids

| 82       | C_{26}H_{37}NO_{3} | 9                      | colorless oil        | Aspergillus sp. ZJ-68 | fresh leaves of the mangrove plant Kandelia candel | Guangdong Province, China | Exhibit inhibitory effects on lipopolysaccharide-induced nitric oxide production in RAW 264.7 macrophage cells (89–91) | [38] |
| 83       | C_{25}H_{35}NO_{3} | 9                      |                      |                   |            |                |                     |      |
| 84       | C_{25}H_{35}NO_{2} | 9                      |                      |                   |            |                |                     |      |
| 85       | C_{26}H_{39}NO_{3} | 8                      |                      |                   |            |                |                     |      |
| 86       | C_{25}H_{34}O_{3}  | 9                      |                      |                   |            |                |                     |      |
| 87       | C_{25}H_{36}O_{4}  | 8                      |                      |                   |            |                |                     |      |
| 88       | C_{25}H_{36}O_{3}  | 8                      |                      |                   |            |                |                     |      |
| 89       | C_{25}H_{36}O_{4}  | 8                      |                      |                   |            |                |                     |      |
| 90       | C_{25}H_{34}O_{3}  | 9                      |                      |                   |            |                |                     |      |
| 91       | C_{25}H_{36}O_{5}  | 7                      |                      |                   |            |                |                     |      |
| 92       | C_{25}H_{36}O_{3}  | 7                      |                      |                   |            |                |                     |      |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology           | Endophytic Fungus                        | Host Plant | Site and Nation | Biological Activity                                      | Ref. |
|----------|-------------------|------------------------|-------------------------------|-----------------------------------------|------------|----------------|----------------------------------------------------------|------|
| 93       | C<sub>30</sub>H<sub>40</sub>O<sub>6</sub> | 11                     | yellowish needle crystals      | Kadsura angustifolia & Penicillium sp. | fresh healthy branches of *K. angustifolia* | China       | Moderate cytotoxic activity (93–100)                      | [39] |
| 94       | C<sub>30</sub>H<sub>40</sub>O<sub>6</sub> | 11                     | white needle crystals          |                                         |            |                |                                                          |      |
| 95       | C<sub>30</sub>H<sub>40</sub>O<sub>6</sub> | 11                     | white amorphous solid         |                                         |            |                |                                                          |      |
| 96       | C<sub>30</sub>H<sub>40</sub>O<sub>6</sub> | 11                     |                                |                                         |            |                |                                                          |      |
| 97       | C<sub>32</sub>H<sub>44</sub>O<sub>7</sub> | 11                     | white amorphous powder        |                                         |            |                |                                                          |      |
| 98       | C<sub>30</sub>H<sub>42</sub>O<sub>6</sub> | 10                     | white powder                  |                                         |            |                |                                                          |      |
| 99       | C<sub>34</sub>H<sub>48</sub>O<sub>8</sub> | 12                     | yellow amorphous solid        |                                         |            |                |                                                          |      |
| 100      | C<sub>31</sub>H<sub>44</sub>O<sub>6</sub> | 10                     | yellow amorphous solid        |                                         |            |                |                                                          |      |
| 101      | C<sub>30</sub>H<sub>46</sub>O<sub>6</sub> | 8                      | white amorphous powder        |                                         |            |                |                                                          |      |
| 102      | C<sub>17</sub>H<sub>24</sub>O<sub>5</sub> | 5                      | colorless oil                 | Phyllosticta capitalensis              | leaves of *Cephalotaxus fortunei* Hook | Shanxi Province, China | Show weak cytotoxic activities against Hela cells. (113–114) | [40] |
| 103      | C<sub>17</sub>H<sub>22</sub>O<sub>5</sub> | 6                      |                               |                                         |            |                |                                                          |      |
| 104      | C<sub>17</sub>H<sub>22</sub>O<sub>5</sub> | 7                      |                               |                                         |            |                |                                                          |      |
| 105      | C<sub>22</sub>H<sub>32</sub>O<sub>6</sub> | 7                      |                               |                                         |            |                |                                                          |      |
| 106      | C<sub>17</sub>H<sub>26</sub>O<sub>5</sub> | 5                      |                               |                                         |            |                |                                                          |      |
| 107      | C<sub>15</sub>H<sub>20</sub>O<sub>5</sub> | 6                      |                               |                                         |            |                |                                                          |      |
| 108      | C<sub>15</sub>H<sub>20</sub>O<sub>5</sub> | 6                      |                               |                                         |            |                |                                                          |      |
| 109      | C<sub>15</sub>H<sub>20</sub>O<sub>5</sub> | 6                      |                               |                                         |            |                |                                                          |      |
| 110      | C<sub>17</sub>H<sub>22</sub>O<sub>6</sub> | 7                      |                               |                                         |            |                |                                                          |      |
| 111      | C<sub>15</sub>H<sub>20</sub>O<sub>5</sub> | 6                      |                               |                                         |            |                |                                                          |      |
### Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 112      | C₁₅H₂₀O₄          | 6                      | colorless oil        |                   |            |                |                     |      |
| 113      | C₁₇H₂₀O₅          | 7                      |                      |                   |            |                |                     |      |
| 114      | C₁₇H₂₂O₅          | 7                      |                      |                   |            |                |                     |      |
| 115      | C₁₆H₂₄O₅          | 5                      |                      |                   |            |                |                     |      |
| 116      | C₂₁H₃₂O₃          | 6                      | yellow oil           | Fusarium oxysporum ZZP-R1 | coastal plant Rumex madaio Makino | Putuo Island (Zhoushan, China) | Antimicrobial activity | [30] |
| 117      | C₁₂H₂₀O₄          | 3                      | yellow oil           | Diaporthe lithocarpus A740 | from the twigs of medicinal plant Morinda officinalis | Guangdong province China |                    | [41] |
|          |                   |                        |                      |                   |            |                |                     |      |
|          |                   |                        |                      | Ketones           |            |                |                     |      |
| 118      | C₂₀H₂₂O₄N₂        | 6                      | white powder         | Eupenicillium sp. LG41 | Chinese medicinal plant Xanthium sibiricum | China | Cytotoxic activity Antimicrobial activity (Antibacterial) | [42] |
| 119      | C₃₈H₅₉O₆N        | 10                     |                      |                   |            |                |                     |      |
| 120      | C₁₂H₁₆O₅          | 4                      | colorless crystals   |                   |            |                |                     |      |
| 121      | C₁₂H₁₈O₅          | 4                      | colorless powders    |                   |            |                |                     |      |
| 122      | C₁₁H₁₄O₅          | 6                      | Brown needles        | Phomopsis sp. sh917 | fresh stems of I. criocarpa var. laxiflora | Kunming, China |                    | [43] |
| 123      | C₂₀H₂₆O₁₀         | 8                      | colorless needles    |                   |            |                |                     |      |
| 124      | C₁₃H₁₄O₅          | 7                      | brown solids         |                   |            |                |                     |      |
| 125      | C₁₇H₂₀O₃          | 8                      | white amorphous powder |                   |            |                |                     |      |
| 126      | C₁₄H₁₆O₄          | 6                      |                      |                   |            |                |                     |      |
| 127      | C₁₂H₁₄O₄          | 5                      |                      |                   |            |                |                     |      |
| 128      | C₁₂H₁₆O₄          | 4                      |                      |                   |            |                |                     |      |
| 129      | C₁₂H₁₄O₄          | 6                      |                      |                   |            |                |                     |      |
| 130      | C₁₇H₂₄O₄          | 7                      |                      |                   |            |                |                     |      |
| 131      | C₁₇H₂₄O₅          | 6                      |                      |                   |            |                |                     |      |
| 132      | C₁₇H₂₄O₅          | 6                      |                      |                   |            |                |                     |      |
| 133      | C₁₇H₂₄O₅          | 6                      |                      |                   |            |                |                     |      |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 132      | C_{18}H_{28}O_{6}  | 5                      |                      |                   |            |                |                     |      |
| 133      | C_{17}H_{22}O_{5}  | 7                      |                      |                   |            |                |                     |      |
| 134      | C_{17}H_{22}O_{5}  | 7                      |                      |                   |            |                |                     |      |
| 135      | C_{11}H_{12}O_{5}  | 6                      | pale yellow powder  |                  |            |                |                     |      |
| 136      | C_{9}H_{8}O_{5}    | 6                      |                      |                  |            |                |                     |      |
| 137      | C_{10}H_{10}O_{5}  | 6                      | yellow powder        |                  |            |                |                     |      |
| 138      | C_{15}H_{20}O_{6}  | 6                      |                      |                  |            |                |                     |      |
| 139      | C_{14}H_{16}O_{6}  | 7                      |                      |                  |            |                |                     |      |
| 140      | C_{15}H_{16}O_{6}  | 8                      | pale yellow powder   | Penicillium chrysogenum | MT-12     | Huperzia serrata (Thunb. ex Murray) Trev. | Fujian Province, China | Exhibit inhibition of nitric oxide production in lipopolysaccharide (LPS)-stimulated RAW264.7 macrophage cells (138,139,142,143,145,146) | [45] |
| 141      | C_{15}H_{18}O_{6}  | 7                      |                      |                  |            |                |                     |      |
| 142      | C_{15}H_{20}O_{6}  | 6                      |                      |                  |            |                |                     |      |
| 143      | C_{16}H_{22}O_{7}  | 6                      | yellow powder        |                  |            |                |                     |      |
| 144      | C_{15}H_{20}O_{5}  | 6                      |                      |                  |            |                |                     |      |
| 145      | C_{15}H_{20}O_{5}  | 6                      |                      |                  |            |                |                     |      |
| 146      | C_{15}H_{20}O_{5}  | 6                      |                      |                  |            |                |                     |      |
| 147      | C_{14}H_{12}O_{6}  | 9                      | yellow powder        | Phomopsis sp. xy21 | fresh roots of Sapium ellipticum | Haut Plateaux region, Cameroon |                     | [46] |
| 148      | C_{14}H_{12}O_{7}  | 9                      |                      |                  |            |                |                     |      |
| 149      | C_{13}H_{10}O_{7}  | 9                      |                      |                  |            |                |                     |      |
| 150      | C_{14}H_{12}O_{6}  | 9                      | yellow crystals      |                  |            |                |                     |      |
| 151      | C_{15}H_{12}O_{7}  | 8                      | colorless crystals   |                  |            |                |                     |      |
| 152      | C_{15}H_{18}O_{7}  | 8                      |                      |                  |            |                |                     |      |
| 153      | C_{15}H_{18}O_{5}  | 8                      |                      |                  |            |                |                     |      |
| 154      | C_{15}H_{12}O_{6}  | 10                     | White amorphous solid | Phomopsis sp. xy21 | leaves of the Thai mangrove Xylocarpus granatum | Trang Province, Thailand | Weak anti-HIV activity (150) | [47] |
| 155      | C_{15}H_{10}O_{7}  | 11                     |                      |                  |            |                |                     |      |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|-----------------|---------------------|------|
| 156      | C_{17}H_{28}O_{3}  | 4                      | white powder         | Aspergillus flocculus | stem of the medicinal plant Markhamia platycalyx |          |                  |                    | [48] |
| 157      | C_{10}H_{10}O_{4}  | 6                      | colorless crystals   | Colletotrichum gloeosporioides | mangrove Ceriops tagal | Hainan Province, China | Show potent antibacterial activity (157,159) | [49] |
| 158      | C_{10}H_{14}O_{4}  | 4                      | brown oil            |                   |            |                  |                    |      |
| 159      | C_{10}H_{12}O_{3}  | 5                      | white powder         |                   |            |                  |                    |      |
| 160      | C_{14}H_{18}O_{4}  | 6                      | amorphous powder     |                   |            |                  |                    |      |
| 161      | C_{14}H_{18}O_{5}  | 6                      |                      |                   |            |                  |                    |      |
| 162      | C_{14}H_{16}O_{6}  | 7                      |                      |                   |            |                  |                    |      |
| 163      | C_{12}H_{18}O_{6}  | 5                      |                      |                   |            |                  |                    |      |
| 164      | C_{22}H_{20}O_{4}  | 13                     |                      |                   |            |                  |                    |      |
| 165      | C_{14}H_{16}O_{6}  | 7                      | pale brown, amorphous powder |                   |            |                  |                    |      |
| 166      | C_{15}H_{12}O_{8}  | 10                     | pale yellow amorphous powder | Alternaria alternata MT-47 | medicinal plant of Huperzia serrata | Fujian Province, China | Exhibit inhibitory activity on the ATP release of thrombin-activated platelets (168) | [51] |
| 167      | C_{18}H_{16}O_{9}  | 10                     | white amorphous powder |                   |            |                  |                    |      |
| 168      | C_{18}H_{20}O_{9}  | 9                      |                      |                   |            |                  |                    |      |
| 169      | C_{10}H_{11}NO_{4} | 6                      |                      |                   |            |                  |                    |      |
| 170      | C_{10}H_{10}O_{5}  | 6                      | white gum            | Chaetosphaeronema achilleae | shoots | English Yew (Taxus baccata), Iran | Weak antifungal activity and antibacterial activity (170) Cytotoxicity (169,170) Biofilm formation (169) | [52] |
| 171      | C_{27}H_{38}O_{6}  | 9                      | colorless oil        | Aspergillus porosus | algal      |                  |                    | [53] |
| 172      | C_{27}H_{38}O_{6}  | 9                      |                      |                   |            |                  |                    |      |
| 173      | C_{26}H_{38}O_{6}  | 9                      |                      |                   |            |                  |                    |      |
| 174      | C_{26}H_{38}O_{6}  | 9                      |                      |                   |            |                  |                    |      |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|-----|
| 175      | C_{25}H_{38}O_{3}  | 7                      | colorless oil        | Alternaria alternate | leaves of Psidium littorale Raddi | Fujian Province, China | Show strong antibacterial activity (176) | [26] |
| 176      | C_{29}H_{30}O_{10} | 15                     | amorphous powder     | Phoma sp. SYSU-SK-7 | healthy branch of the marine Kandelia candel | Guangxi Province, China | Exhibits significant antifungal and antibacterial activity (177) | [54] |
| 177      | C_{11}H_{14}O_{4}  | 5                      | white solid          | Phoma sp. D15a2a   | leaves of Alternanthera bettzickiana (Amaranthaceae) | Anambra state of Nigeria | Show significant α-glucosidase inhibitory activity (176–178) | [55] |
| 178      | C_{21}H_{24}O_{7}  | 10                     | white solid          | Penicillium purpureum IMM003 | fresh healthy leaves of Edgeworthia chrysantha | Zhejiang Province, China | Cytotoxicity (176) | [56] |
| 179      | C_{13}H_{12}O_{5}  | 8                      |                      |                   |            |                | Exhibit radical scavenging activity against DPPH (179) | |
| 180      | C_{11}H_{16}O_{3}  | 4                      | colourless oil       |                   |            |                |                     |     |
| 181      | C_{10}H_{14}O_{3}  | 4                      | Phomopsis sp. D15a2a | leaves of Alternanthera bettzickiana (Amaranthaceae) |            | Anambra state of Nigeria |                     |     |
| 182      | C_{11}H_{16}O_{4}  | 4                      |                      |                   |            |                |                     |     |
| 183      | C_{11}H_{16}O_{4}  | 4                      |                      |                   |            |                |                     |     |
| 184      | C_{23}H_{38}O_{7}  | 11                     |                      |                   |            |                |                     |     |
| 185      | C_{22}H_{26}O_{6}  | 10                     | Penicillium purpurigenum IMM003 | fresh healthy leaves of Edgeworthia chrysantha | Zhejiang Province, China | Cytotoxicity (176) | [57] |
| 186      | C_{10}H_{8}O_{5}   | 7                      | Camporesia sambuci FT1061 & Epicoccum sorghinum FT1062 | healthy fruit of the plant Rhodomyrtus tomentosa | the Big Island in Hawaii | Cytotoxicity (176) | [57] |
| 187      | C_{18}H_{27}NO_{4} | 6                      | colorless gum        |                   |            |                |                     |     |
| 188      | C_{14}H_{20}O_{6}  | 5                      | light yellow solid   | Rhytismataceae sp. DAOMC 251461 | healthy P. mariana needles | New Brunswick, Canada | Exhibit moderate antifungal activity (189) | [58] |
| 189      | C_{15}H_{22}O_{6}  | 5                      |                     |                   |            |                |                     |     |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 190      | C₉H₁₂O₆           | 4                      | colorless plate      | *Phomopsis asparagi* | fresh, healthy branches of medicinal plant *Kadsura angustifolia* | Yunnan province, China | Exhibit notable cytotoxicity (192–194) | [59] |
| 191      | C₈H₁₀O₅           | 4                      | colorless crystals   |                   |            |                |                     |      |
| 192      | C₉H₁₀O₆           | 5                      | colorless crystals   |                   |            |                |                     |      |
| 193      | C₁₁H₁₂O₄          | 5                      | colorless plates     |                   |            |                |                     |      |
| 194      | C₁₁H₁₄O₅          | 5                      | colorless plates     |                   |            |                |                     |      |
| 195      | C₁₄H₁₈O₄          | 6                      | colorless oil        | *Dendrothyrium variisporum* | roots of the Algerian plant *Globularia alypum* | Ain Tota, Batna 05000 (Algeria) |                     | [60] |
| 196      | C₁₈H₂₄O₅          | 7                      | colorless oil        | *Alternaria sp.*   | twigs of *Morinda officinalis* | Guangdong province, China |                     | [61] |
| 197      | C₁₁H₁₀O₅          | 7                      | colorless oil        | *Alternaria sp.*   | twigs of *Morinda officinalis* | Guangdong province, China |                     | [61] |
| 198      | C₁₂H₁₁O₅          | 8                      | yellow oil           |                   |            |                |                     |      |
| 199      | C₈H₁₂O₃           | 3                      | colorless gum        | *Trichoderma atroviride* | bulb of *Lycoris radiata* | Hubei Province, China |                     | [11] |
| 200      | C₁₃H₁₄O₅          | 7                      | yellow viscous liquid| *Eurotium chevalieri* KUFA 0006 | healthy twig of *Rhizophora mucronata* | Chanthaburi Province, Eastern Thailand | Prevent biofilm formation | [62] |
| 201      | C₉H₁₄O₄           | 3                      | colorless gum        | *Simplicillium* sp. PSU-H41 | leaf of *Hevea brasiliensis* | Songkhla Province, Thailand |                     | [63] |
| 202      | C₁₅H₁₂O₈           | 10                     | yellowish crystal    |                   |            |                |                     |      |
| 203      | C₁₄H₁₄O₆           | 10                     | brown gum            |                   |            |                |                     |      |
| 204      | C₁₄H₆O₇           | 11                     | yellowish green powder| *Cytopora rhizophorae* | *Morinda officinalis* | Guangdong province, China | Exhibit weak growth inhibitory activity against the tumor cell lines (202) | [64] |
| 205      | C₁₃H₁₆O₅           | 6                      | yellow gum           |                   |            |                |                     |      |
| 206      | C₁₄H₁₄O₄           | 8                      | red crystals         |                   |            |                |                     |      |
| 207      | C₁₆H₁₆O₆           | 8                      | red solid            |                   |            |                |                     |      |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology       | Endophytic Fungus          | Host Plant                  | Site and Nation              | Biological Activity                                      | Ref. |
|----------|-------------------|------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------------------------------------|------|
| 208      | C_{18}H_{17}ClO_{7} | 10                     | yellowish powder            | *Penicillium citrinum*      | mangrove *Bruguiera sexangula var. rhynchopetala* | South China Sea | Display cytotoxic activity (209) Show weak antibacterial activity (208) | [66] |
| 209      | C_{18}H_{16}O_{7}  | 10                     | amorphous white powder      | *Phoma* sp. PF2             | *Artemisia princeps*        |                            | Show moderate inhibitory activities on nitric oxide levels (210–211) | [67] |
| 210      | C_{13}H_{16}O_{5}  | 6                      | polar yellow solid          | *Aspergillus* sp. ASCLA     | healthy leaf tissue of the medicinal plant *Callistemon subulatus* |                            | Exert moderate-high activities against *Staphylococcus aureus* | [68] |
| 211      | C_{14}H_{18}O_{5}  | 6                      | amorphous white powder      | *Cylindrocarpon* sp.        | fresh roots of *Sapium ellipticum* | Haut Plateaux region, Cameroon |                            | [46] |
| 212      | C_{25}H_{26}O_{5}  | 13                     | yellow oil                  | *Diaporthe* lithocarpus A740 | twigs of medicinal plant *Morinda officinalis* | Guangdong province China |                            | [41] |
| 213      | C_{12}H_{18}O_{3}  | 4                      | colorless amorphous solid   | *Chaetomium* globosum CDW7  | lichen *Cladonia* sp.       |                            |                            | [37] |
| 214      | C_{25}H_{26}O_{6}  | 12                     | colorless powder            | *Bionectria* sp.            | seeds of the tropical plant *Raphia taedigera* | Haut Plateaux region, Cameroon |                            | [70] |
| 215      | C_{26}H_{33}O_{8}N | 11                     | colorless crystals          | *Apiospora montagnae*       | *Sapium ellipticum*         | Haupt Plateaux region, Cameroon |                            | [41] |
| 216      | C_{16}H_{19}NO_{3} | 8                      | colorless amorphous solid   | *Chaetomium globosum CDW7*  | lichen *Cladonia* sp.       |                            |                            | [69] |
| 217      | C_{17}H_{24}N_{2}O_{3} | 7               | colorless crystals          | *Penicillium citrinum*      | mangrove *Bruguiera sexangula var. rhynchopetala* | South China Sea |                            | [66] |
| 218      | C_{13}H_{15}NO_{2} | 7                      | colorless powder            | *Bionectria* sp.            | seeds of the tropical plant *Raphia taedigera* | Haut Plateaux region, Cameroon |                            | [70] |
| 219      | C_{16}H_{15}NO_{5} | 10                     | yellow powder               | *Cylindrocarpon* sp.        | fresh roots of *Sapium ellipticum* | Haut Plateaux region, Cameroon |                            | [46] |
| 220      | C_{14}H_{21}NO_{3} | 5                      | white powder                | *Cylindrocarpon* sp.        | fresh roots of *Sapium ellipticum* | Haut Plateaux region, Cameroon |                            | [46] |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology       | Endophytic Fungus      | Host Plant                                                                 | Site and Nation     | Biological Activity                                                                 |
|----------|------------------|------------------------|-----------------------------|------------------------|-------------------------------------------------------------------------------|---------------------|--------------------------------------------------------------------------------------|
| 221      | C_{26}H_{29}NO_{6} | 13                     | pale yellow amorphous solid | Aspergillus versicolor  | leaves of the Egyptian water hyacinth Eichhornia crassipes                     | Egypt               | Exhibit moderate antiproliferative activity                                           |
| 222      | C_{17}H_{15}NO_{6} | 11                     | white amorphous solid       | Pestalotiopsis flavidula | branches of Cinnamomum camphora                                                 | Yunnan province china | Moderate cytotoxicity (222–223)                                                      |
| 223      | C_{10}H_{24}N_{2}O_{2} | 9                      | white amorphous powder      | Irpex lacteus-A         | medicinal plant Huperzia serrata                                                | Fujian Province China | Show moderate neuroprotective activity (224–225)                                      |
| 224      | C_{19}H_{24}N_{2}O_{2} | 9                      | white amorphous powder      | Alternaria alternate    | leaves of Psidium littorale Raddi                                               | Fujian Province, China | Show potent inhibitory effects (227–228)                                              |
| 225      | C_{19}H_{24}N_{2}O_{2} | 9                      | white amorphous powder      | Pestalotiopsis sp. HHL-101 | fresh leaves of cultivated tobacco (N. tabacum L.). N. tabacum L.              | Hubei province China | Exhibit remarkable larvicidal activity (228)                                          |
| 229      | C_{10}H_{14}O_{5}  | 4                      | clear solid                | Mycosphaerellaceae sp. DAOMC 250863 | healthy needles from Picea rubens (red spruce) and P. mariana (black spruce) | Eastern Canada | Show modest antibiotic activity to E. coli                                           |
| 230      | C_{16}H_{18}O_{4} | 8                      | light-yellow powder         | C. globosum CDW7        | Ginkgo biloba                                                                  | China               | Show moderate antifungal activity                                                   |
| 231      | C_{12}H_{14}O_{4} | 6                      | colorless amorphous solid   | Pestalotiopsis sp. HHL-101 | fresh twigs of the mangrove plant Rhizophora stylosa                           | Hainan Island, China | Exhibit moderate antibacterial activity                                               |
| 232      | C_{12}H_{12}O_{4} | 7                      | white amorphous powder      | Nectria pseudotrichia 120–1NP | healthy stem of Gliricidia sepium                                               | Yogyakarta, Indonesia |                                                                                  |
| 233      | C_{13}H_{14}O_{4} | 7                      | white amorphous powder      | Pestalotiopsis sp. HHL-101 | fresh leaves of the mangrove plant Rhizophora stylosa                           | Hainan Island, China | Exhibit moderate antibacterial activity                                               |

Penylpropanoids and their derivatives

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology       | Endophytic Fungus      | Host Plant                                                                 | Site and Nation     | Biological Activity                                                                 |
|----------|------------------|------------------------|-----------------------------|------------------------|-------------------------------------------------------------------------------|---------------------|--------------------------------------------------------------------------------------|
| 226      | C_{19}H_{24}N_{2}O_{2} | 9                      | white amorphous powder      | Pestalotiopsis sp. HHL-101 | fresh leaves of cultivated tobacco (N. tabacum L.). N. tabacum L.              | Hubei province China | Show potent inhibitory effects (227–228)                                              |
| 228      | C_{27}H_{31}N_{5}O_{5} | 14                     | brilliant yellowish oil     | Fusarium sambucinum TE-6L | fresh leaves of cultivated tobacco (N. tabacum L.). N. tabacum L.              | Hubei province China | Exhibit remarkable larvicidal activity (228)                                          |
| 230      | C_{16}H_{18}O_{4} | 8                      | light-yellow powder         | C. globosum CDW7        | Ginkgo biloba                                                                  | China               | Show moderate antifungal activity                                                   |
| 231      | C_{12}H_{14}O_{4} | 6                      | colorless amorphous solid   | Pestalotiopsis sp. HHL-101 | fresh twigs of the mangrove plant Rhizophora stylosa                           | Hainan Island, China | Exhibit moderate antibacterial activity                                               |
| 232      | C_{12}H_{12}O_{4} | 7                      | white amorphous powder      | Nectria pseudotrichia 120–1NP | healthy stem of Gliricidia sepium                                               | Yogyakarta, Indonesia |                                                                                  |
| 233      | C_{13}H_{14}O_{4} | 7                      | white amorphous powder      | Pestalotiopsis sp. HHL-101 | fresh leaves of the mangrove plant Rhizophora stylosa                           | Hainan Island, China | Exhibit moderate antibacterial activity                                               |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 234      | C_{21}H_{12}O_{12} | 16                     | off-white amorphous solid | Aspergillus versicolor | leaves of the Egyptian water hyacinth *Eichhornia crassipes* | Egypt | Show weak to moderate cytotoxic activity | [71] |
| 235      | C_{22}H_{14}O_{12} | 16                     | yellowish amorphous powder | | | | | |
| 236      | C_{21}H_{22}O_{6}  | 11                     | colorless crystals | Pestalotiopsis adusta | stem bark of wild rare medicinal plant *Sinopodophyllum hexandrum* (Royle) Ying | Qinling Mountains China | | [19] |
| 237      | C_{13}H_{14}O_{7}  | 7                      | white solid powder | *T. harzianum* Fes1712 | Rubber Tree *Ficus elastica* Leaves | China | Exhibit inhibitory activity against Gram-negative bacteria (237–238) | [76] |
| 238      | C_{11}H_{12}O_{6}  | 6                      | white amorphous powder | *Penicillium coffeae* MA-314 | fresh inner tissue of the leaf of marine mangrove plant *Laguncularia racemosa* | Hainan island, China | | [77] |
| 239      | C_{18}H_{22}O_{3}  | 8                      | yellow oil | *Diaporthe* sp. | branches of *Pteroceltis tatarinowii* Maxim | Nanjing province, China | Show modest antibacterial activity Weak cytotoxicity | [78] |
|          |                    |                        |                      | *Alternaria* sp. | seeds of the plant *Ziziphus jujuba* | Uzbekistan | | [79] |
| 242      | C_{16}H_{26}O_{6}  | 4                      | yellowish brown solid | *Alternaria* sp. | seeds of the plant *Ziziphus jujuba* | Uzbekistan | | [79] |
| 243      | C_{16}H_{26}O_{5}  | 4                      | white, amorphous powder | *Phaeoacremonium* sp. | leaves of *Senna spectabilis* | Araraquara Cerrado area, Sao Paulo state, Brazil. | Exhibit antifungal activity (244–245) Cytotoxicity (244) | [80] |

**Lactones**

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 244      | C_{16}H_{26}O_{5}  | 4                      | white, amorphous powder | *Phaeoacremonium* sp. | leaves of *Senna spectabilis* | Araraquara Cerrado area, Sao Paulo state, Brazil. | Exhibit antifungal activity (244–245) Cytotoxicity (244) | [80] |

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*Table 1. Cont.*
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|------------------|------------|----------------|---------------------|------|
| 246      | C₉H₁₂O₂           | 4                      | amorphous powder     | Xylaria curta    | 92092022   | barks          | Taiwan             | China [81] |
| 247      | C₁₆H₂₂O₅          | 6                      | white powder         | Trichoderma sp.  | 307        | Strain 307, stem bark of Clerodendrum inerme | Guangdong Province, China | Exhibit potent α-glucosidase inhibitory activity (247–248) show moderate inhibitory activity against α-glucosidase (249) [10] |
| 249      | C₁₆H₂₀O₅          | 7                      | colorless needles    | Pestalotiopsis sp. | 307        | Strain 307, stem bark of Clerodendrum inerme | Guangdong Province, China | Exhibit selective cytotoxicities [82] |
| 250      | C₁₀H₁₆O₃           | 3                      | colorless oil        | Pestalotiopsis sp. | 307        | fruits of Drepanocarpus lunatus (Fabaceae) | Guangdong Province, China | Exhibit antibacterial activity [83] |
| 251      | C₁₃H₁₈O₅           | 5                      | colorless oil        | Talaromyces sp. | 307        | Xanthoparmelia angustiphylla | Stockholm, Sweden | Exhibit antibacterial activity [85] |
| 252      | C₁₁H₁₄O₅           | 5                      | colorless crystals   | Talaromyces sp. | 307        | Xanthoparmelia angustiphylla | Stockholm, Sweden | Exhibit antibacterial activity [83] |
| 253      | C₃₂H₅₀O₇           | 8                      | yellow powder        | Mutant CS/asm21-4 | 307        | Maytenus hookeri | China | Exhibit antibacterial activity [83] |
| 254      | C₂₂H₂₁NO₄         | 13                     | light yellow gum     | Aspergillus terreus | 307        | Yongxing Island fresh, healthy leaves of S. maritima L. | South China Sea, China | Show strong inhibitory effects on the production of NO (256–257) [84] |
| 255      | C₂₂H₁₉O₄           | 14                     | light yellow gum     | Aspergillus terreus | 307        | Yongxing Island fresh, healthy leaves of S. maritima L. | South China Sea, China | Show strong inhibitory effects on the production of NO (256–257) [84] |
| 256      | C₂₂H₂₁NO₃         | 13                     | colorless oil        | Aspergillus terreus | 307        | Yongxing Island fresh, healthy leaves of S. maritima L. | South China Sea, China | Show strong inhibitory effects on the production of NO (256–257) [84] |
| 257      | C₂₂H₂₁NO₃         | 13                     | colorless oil        | Aspergillus terreus | 307        | Yongxing Island fresh, healthy leaves of S. maritima L. | South China Sea, China | Show strong inhibitory effects on the production of NO (256–257) [84] |
| 258      | C₂₀H₂₂O₃           | 10                     | yellow oil           | Aspergillus sp. | 307        | root of Tripterygium wilfordii | Wuhan, China | Exhibited weak AchE and BACE1 inhibitory activity (260–261) Showed excellent inhibitory effects on the production of IL-1β, TNF-α, and NO (258–261) [85] |
| 259      | C₂₄H₂₆O₆           | 12                     | yellow oil           | Aspergillus sp. | 307        | root of Tripterygium wilfordii | Wuhan, China | Exhibited weak AchE and BACE1 inhibitory activity (260–261) Showed excellent inhibitory effects on the production of IL-1β, TNF-α, and NO (258–261) [85] |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|------------------|------------|----------------|---------------------|-----|
| 262      | C_{22}H_{36}O_{8} | 5                      | oil                  | H. fuscum        | lichen Usnea sp. | Yunnan, China  | Exhibit moderate cytotoxicity | [86]|
| 263      | C_{26}H_{34}O_{12} | 10                     | white powder         | Talaromyces purpurogenus | fresh leaves of the toxic medicinal plant Tylophora ovata | China |                     | [87]|
| 264      | C_{28}H_{36}O_{12} | 11                     | white powder         | Talaromyces purpurogenus | fresh inner tissue of the leaf of marine mangrove plant Laguncularia racemosa | Hainan island, China | Exhibit potent antifungal activity | [77]|
| 265      | C_{26}H_{40}O_{9}  | 7                      | yellow oil           | Penicillium coffeae MA-314 | fresh inner tissue of the leaf of marine mangrove plant Laguncularia racemosa | Hainan island, China | Exhibit potent antifungal activity | [77]|
| 266      | C_{11}H_{18}O_{3}  | 3                      | yellow oil           | Penicillium coffeae MA-314 | fresh inner tissue of the leaf of marine mangrove plant Laguncularia racemosa | Hainan island, China | Exhibit potent antifungal activity | [77]|
| 267      | C_{12}H_{12}O_{5}  | 7                      | brown solids         | Phomopsis sp.     | stems of Isodon eriocalyx var. laxiflora | Kunming, China |                     | [43]|
| 268      | C_{17}H_{14}O_{3}  | 11                     | white amorphous powder | Phyllosticta sp. J13-2-12Y | leaves of Acorus tatarinovii | Guangxi Province, China |                     | [88]|
| 269      | C_{19}H_{18}O_{5}  | 12                     | colorless oil        | Phyllosticta sp. J13-2-12Y | leaves of Acorus tatarinovii | Guangxi Province, China |                     | [88]|
| 270      | C_{16}H_{12}O_{3}  | 11                     | colorless crystal    | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|
| 271      | C_{22}H_{26}O_{6}  | 10                     | luminous yellow oil  | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|
| 272      | C_{19}H_{16}O_{5}  | 12                     | colorless crystal    | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|
| 273      | C_{16}H_{14}O_{5}  | 6                      | yellow amorphous powder | Penicillium citrinum Salicornia 46 | Salicornia herbacea Torr. | China |                     | [90]|
| 274      | C_{14}H_{14}O_{4}Cl_{2} | 7                 | yellow oil           | Lachnum cf. pygmaeum DAOMC 250335 | dead P. rubens twig NB, Canada | | Inhibit the growth of M. violaceum, | [58]|
| 275      | C_{16}H_{12}O_{6}  | 11                     | luminous yellow oil  | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|
| 276      | C_{18}H_{14}O_{7}  | 12                     | yellow crystal       | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|

Anthraquinones

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|------------------|------------|----------------|---------------------|-----|
| 273      | C_{12}H_{14}O_{5}  | 6                      | yellow amorphous powder | Penicillium citrinum Salicornia 46 | Salicornia herbacea Torr. | China |                     | [90]|
| 274      | C_{14}H_{14}O_{4}Cl_{2} | 7                 | yellow oil           | Lachnum cf. pygmaeum DAOMC 250335 | dead P. rubens twig NB, Canada | | Inhibit the growth of M. violaceum, | [58]|
| 275      | C_{16}H_{12}O_{6}  | 11                     | luminous yellow oil  | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|
| 276      | C_{18}H_{14}O_{7}  | 12                     | yellow crystal       | Eurotium chevalieri KUFA 0006 | healthy twig of Rhizophora mucronata Poir. | Chanthaburi Province, Eastern Thailand | Cause a significant reduction in biofilm production | [62]|

Table 1. Cont.
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|----------------------|------|
| 277      | C_{15}H_{16}O_{3} | 8                      |                      | Nigrospora oryzae co-cultured with Irpex lacteus | seeds of Dendrobium officinale | Yunnan Province, China |                      | [14] |
| 278      | C_{15}H_{16}O_{2} | 7                      |                      |                   |            |                |                      |      |
| 279      | C_{15}H_{20}O_{4} | 6                      |                      |                   |            |                |                      |      |
| 280      | C_{15}H_{20}O_{6} | 6                      |                      |                   |            |                |                      |      |
| 281      | C_{14}H_{16}O_{2} | 7                      |                      | Neofusicoccum austral SYSU-SKS024 | branches of the mangrove plant Kandelia candel | Guangxi province, China | Show inhibitory effects against Indoleamine 2,3-dioxygenase (IDO) | [92] |
| 282      | C_{14}H_{16}O_{3} | 7                      |                      | Phoma betae Kalidium foliatum (Pall.) | China | Cytotoxic activities (281) |                      | [91] |
| 283      | C_{14}H_{20}O_{5} | 5                      |                      | Nectria pseudotrichia 120-1NP | healthy stem of Gliricidia sepium | Yogyakarta, Indonesia | Exhibit antibacterial activity | [31] |
| 284      | C_{27}H_{34}O_{10} | 16                     | red powder           |                   |            |                |                      |      |
| 285      | C_{15}H_{16}O_{6} | 8                      | yellow powder        |                   |            |                |                      |      |
| 286      | C_{14}H_{18}O_{5} | 6                      | white powder         |                   |            |                |                      |      |
| 287      | C_{16}H_{18}O_{5} | 8                      | yellow amorphous powder |                   |            |                |                      |      |
| 288      | C_{30}H_{22}O_{12} | 20                     | yellow powder        | ARL-09 (Diaporthe sp.) | Anoectochilus roxburghii | China | Cytotoxicity Effects on NF-κB signaling pathway | [93] |
| 289      | C_{40}H_{45}NO_{10}S | 19                     | red powder           |                   |            |                |                      |      |
| 290      | C_{40}H_{49}NO_{12} | 17                     | yellow powder        | CS/asm21-4 | callus of Chinese medicinal plant Maytenus hookeri | China | Show moderate antimicrobial activities (antibacterial activities and antifungal activity) (289–291) | [83] |
| 291      | C_{40}H_{44}NO_{9}Cl | 19                     |                      |                   |            |                |                      |      |
| 292      | C_{12}H_{16}O_{6} | 4                      | colorless oil        | Xylaria sp. SYPF 8246 | root of Panax notoginseng | Yunnan, China |                      | [94] |
| 293      | C_{15}H_{14}O_{6} | 9                      |                      | Talaromyces funiculosus | lichen thallus of Diorygma hieroglyphicum | India | Display antimicrobial activity | [95] |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 294      | C\textsubscript{16}H\textsubscript{14}O\textsubscript{7} | 10 | yellow gum | Simplicillium lanosoniveum | leaves of Hevea brasiliensis | Songkhla Province, Thailand | Display antifungal activity | [96] |
| 295      | C\textsubscript{17}H\textsubscript{18}O\textsubscript{7} | 9 | red amorphous powder | Fusarium napiforme | mangrove plant, Rhizophora mucronata | Makassar, Indonesia | Exhibit moderate antibacterial activity (295–296) Phytotoxic (295–296) | [97] |
| 296      | C\textsubscript{16}H\textsubscript{16}O\textsubscript{6} | 9 | orange amorphous powder | Sterides | | | | |
| 297      | C\textsubscript{34}H\textsubscript{32}O\textsubscript{8} | 9 | faint yellow oil | Xylaria sp. | leaves of Panax notoginseng | Yunnan province, China | Show cytotoxicity (297) | [98] |
| 298      | C\textsubscript{28}H\textsubscript{44}O\textsubscript{7} | 7 | semitransparent oil | | | | | |
| 299      | C\textsubscript{25}H\textsubscript{36}O\textsubscript{5} | 8 | colorless needle | | | | | |
| 300      | C\textsubscript{25}H\textsubscript{36}O\textsubscript{5} | 8 | colorless amorphism | Chaetomium sp. M453 | Chinese herbal medicine Huperzia serrata | Yunnan Province, China | Show weak acetylcholinesterase inhibitory activity (302) | [99] |
| 301      | C\textsubscript{25}H\textsubscript{34}O\textsubscript{5} | 9 | | | | | | |
| 302      | C\textsubscript{28}H\textsubscript{42}O\textsubscript{3} | 6 | | | | | | |
| 303      | C\textsubscript{22}H\textsubscript{32}O\textsubscript{3} | 7 | | | | | | |
| 304      | C\textsubscript{23}H\textsubscript{36}O\textsubscript{3} | 6 | | | | | | |
| 305      | C\textsubscript{21}H\textsubscript{34}O\textsubscript{3} | 7 | colorless needle crystals | Stempphylium sp. AZGP4–2 | root of Polyalthia laui | Hainan Province, China | Show antibacterial activity against Escherichia coli (303) Exhibit antibacterial activity (304) | [100] |
| 306      | C\textsubscript{44}H\textsubscript{72}O\textsubscript{2} | 9 | | | | | | |
| 307      | C\textsubscript{28}H\textsubscript{46}O\textsubscript{3} | 6 | | | | | | |
| 308      | C\textsubscript{30}H\textsubscript{48}O\textsubscript{5} | 7 | | | | | | |
| 309      | C\textsubscript{28}H\textsubscript{46}O\textsubscript{2} | 9 | colorless powder | Pleosporales sp. F46 and Bacillus wiedmannii. Com1 | medicinal plant Mahonia fortunei | Qingdao, China. | Exhibit moderate antibacterial efficacy | [102] |
| 310      | C\textsubscript{32}H\textsubscript{41}NO\textsubscript{3} | 13 | white powder | Aspergillus tubingensis YP-2 | bark of Taxus yunnanensis | Yunnan Province, China | Show weak cytotoxicities (311) | [103] |
| 311      | C\textsubscript{22}H\textsubscript{33}O\textsubscript{3} | 6 | | | | | | |

**Table 1. Cont.**
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|-----|
| 312      | C21H24O6          | 10                     | colorless oil        |                   |            |                | Other types of compounds |     |
| 313      | C23H26O7          | 11                     |                      | Talaromyces stipitatus SK-4 | leaves of a mangrove plant Acanthus ilicifolius | Guangxi Province, China | Show antibacterial activity and inhibitory against α-glucosidase (313) | [104] |
| 314      | C15H21NO8         | 6                      | whitish needles      | C. ninchukispora BCRC 31900 | seeds of medicinal plant Beilschmiedia erythrophloia Hayata | Taiwan, China | Show anti-inflammatory effects through inhibition of NO production (317,314–315) | [105] |
| 315      | C15H21NO7         | 6                      | whitish needles      |                   |            |                | Other types of compounds |     |
| 316      | C16H23NO7         | 6                      | whitish needles      |                   |            |                | Other types of compounds |     |
| 317      | C15H21NO8         | 6                      | yellowish solid      |                   |            |                | Other types of compounds |     |
| 318      | C15H16O5          | 8                      | white amorphous powder |                  | Pyronema sp. (A2-1 & D1-2) Taxus mairei | Hubei province, China | Exhibit moderate antibiotic activity | [106] |
| 319      | C11H16O4          | 4                      | yellow oil           | Phoma sp. nov. LG0217 | branches of Parkinsonia microphylla | Tucson, Arizona |             | [107] |
| 320      | C12H16O4          | 5                      | colorless amorphous powder | Penicillium citrinum Salicornia 46 | Salicornia herbacea Torr | China | Exhibit potent cytotoxic activity | [90] |
| 321      | C21H29NO9         | 8                      | colorless gum         | Phomopsis sp. PSU-H188 | midrib of Hevea brasiliensis | Trang Province, Thailand |             | [108] |
| 322      | C20H28O7          | 7                      | colorless gum         |                   |            |                | Other types of compounds |     |
| 323      | C21H27O8N         | 9                      | yellow amorphous solid |                   |            |                | Other types of compounds |     |
| 324      |                   |                        |                      |                   |            |                | Other types of compounds |     |
| 325      | C21H27O7N         | 9                      | yellow amorphous solid |                   |            |                | Other types of compounds |     |
| 326      |                   |                        |                      |                   |            |                | Other types of compounds |     |
| 327      | C21H25O8N         | 10                     | pale yellow amorphous solid | Fusarium solani JK10 | root of the Ghanaian medicinal plant Chlorophora regia | Eastern Region of Ghana | Exhibit antibacterial efficacies (325–326,328) | [109] |
| 328      | C22H29O7N         | 9                      | yellow amorphous solid |                   |            |                | Other types of compounds |     |
| 329      | C22H29O5N         | 9                      | yellow amorphous solid |                   |            |                | Other types of compounds |     |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 330      | \( \text{C}_{14}\text{H}_{14}\text{O}_4 \) | 8                      | colourless oil       | *Phomopsis longicolla* HL-2232 | fresh healthy leaf of *Bryiera sexangula* var. *rhynchopetala* | South China Sea | Show moderate antibacterial activities | [110] |
| 331      | \( \text{C}_9\text{H}_{16}\text{O}_4 \) | 2                      | white needles        | *Penicillium* sp. OC-4 | leaves of *Orchidantha chinensis* | Guangdong Province, China | Display strong antioxidant activity | [111] |
| 332      | \( \text{C}_{16}\text{H}_{24}\text{O}_6 \) | 5                      | colorless, amorphous solid | *Curvularia* sp. | leaf of the medicinal plant *Murraya koenigii* | Bangladesh | Exhibit zoospore motility impairment activity (333–334) | [112] |
| 333      | \( \text{C}_{10}\text{H}_{12}\text{O}_3 \) | 5                      | colorless crystals    |                    |            |                |                     |      |
| 334      | \( \text{C}_{10}\text{H}_{16}\text{O}_4 \) | 3                      | colorless oil        |                    |            |                |                     |      |
| 335      | \( \text{C}_{20}\text{H}_{16}\text{O}_5 \) | 13                     | yellow viscous oil   | *Rhytidhysteron rufulum* AS21B | leaves of *Azima armentosa* | Samutsakhon province, Thailand | Display the most promising anti-tumor activity (337) | [113] |
| 336      | \( \text{C}_{22}\text{H}_{18}\text{O}_5 \) | 14                     | pale yellow gum      |                    |            |                |                     |      |
| 337      | \( \text{C}_{11}\text{H}_{12}\text{O}_4 \) | 6                      | brown solids         | *Phomopsis* sp. sh917 | stems of *Isodon eriocalyx* var. *laxiflora* | Kunming, China |                     | [43] |
| 338      | \( \text{C}_{13}\text{H}_{15}\text{NO}_3 \) | 9                      | brown gum            | *Dendrothyrium variisporum* | roots of the Algerian plant *Globularia alypum* | Algeria | Show the strongest activity against *Bacillus subtilis* and *Micrococcus luteus* (339) | [60] |
| 339      | \( \text{C}_{14}\text{H}_{13}\text{NO}_2 \) | 9                      | brown gum            |                    |            |                |                     |      |
| 340      | \( \text{C}_{12}\text{H}_{17}\text{NO}_3 \) | 5                      | yellow crystal       | *Trichoderma atrocliride* | bulb of *Lycoris radiata* | china | Display significant antifungal activity and remarkable cytotoxicities | [114] |
| 341      | \( \text{C}_{32}\text{H}_{34}\text{N}_2\text{O}_4 \) | 17                     | light yellow gum     | *Penicillium chrysogenum* V11 | vein of *Myoporum bontoides* A. Gray | Leizhou Peninsula, China |                     |      |
| 342      | \( \text{C}_{13}\text{H}_{15}\text{N}_2\text{O}_4 \) | 8                      | light yellow gum     |                    |            |                |                     |      |
| 343      | \( \text{C}_{14}\text{H}_{15}\text{NO} \) | 8                      | yellow crystal       | *Eurotium chevalieri* KUFA 0006 | healthy twig of *Rhizophora macronata* Poir. | Chanthaburi Province, Eastern Thailand | Show inhibition of biofilm production (344–345) | [62] |
| 344      | \( \text{C}_{14}\text{H}_{15}\text{NO} \) | 8                      | yellow crystal       |                    |            |                |                     |      |
| 345      | \( \text{C}_{13}\text{H}_{15}\text{NO} \) | 8                      | yellowish viscous liquid | *Eurotium chevalieri* KUFA 0006 | healthy twig of *Rhizophora macronata* Poir. | Chanthaburi Province, Eastern Thailand | Show inhibition of biofilm production (344–345) | [62] |
| 346      | \( \text{C}_{13}\text{H}_{15}\text{NO}_3 \) | 7                      | yellow liquid        |                    |            |                |                     |      |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology       | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity                                                                 |
|----------|-------------------|------------------------|---------------------------|-------------------|------------|----------------|-------------------------------------------------------------------------------------|
| 347      | C_{18}H_{18}O_{6} | 10                     | colorless solid           |                   |            |                | Display weak antibacterial against *Staphylococcus aureus* (347)                      |
| 348      | C_{19}H_{20}O_{6} | 10                     | pale yellow solid         |                   |            |                |                                                                                     |
| 349      | C_{20}H_{20}O_{6} | 11                     |                           |                   |            |                |                                                                                     |
| 350      | C_{25}H_{24}O_{7} | 14                     |                           | *Simplicillium* sp. PSU-H41 | leaf of *Hevea brasiliensis* (Euphorbiaceae) | Songkhla, Thailand | Display weak antibacterial against *Staphylococcus aureus* (347) Exhibit weak antifungal activity against *Cryptococcus neoformans* (349) |
| 351      | C_{25}H_{24}O_{7} | 14                     |                           |                   |            |                |                                                                                     |
| 352      | C_{25}H_{22}O_{8} | 15                     | yellow gum                |                   |            |                |                                                                                     |
| 353      | C_{24}H_{26}O_{7} | 12                     | pale yellow gum           |                   |            |                |                                                                                     |
| 354      | C_{34}H_{36}O_{11}| 20                     | colorless solid           |                   |            |                |                                                                                     |
| 355      | C_{31}H_{29}O_{8} | 18                     | pale yellow gum           |                   |            |                |                                                                                     |
| 356      | C_{17}H_{34}N_{2}O_{6} | 7                     |                           | *Phoma herbarum* PSU-H256 | leaf of *Hevea brasiliensis* | Songkhla, Thailand |                                                                                     |
| 357      | C_{12}H_{13}NO_{6} | 7                      | colorless viscous oil     |                   |            |                |                                                                                     |
| 358      | C_{16}H_{19}NO_{7} | 8                      |                           |                   |            |                |                                                                                     |
| 359      | C_{15}H_{17}NO_{5} | 8                      |                           |                   |            |                |                                                                                     |
| 360      | C_{2}H_{12}N_{2}O_{3} | 3                     |                           |                   |            |                |                                                                                     |
| 361      | C_{14}H_{14}N_{2}O_{5} | 9                     |                           |                   |            |                |                                                                                     |
| 362      | C_{11}H_{12}O_{3} | 6                      | white amorphous solid.    | *Penicillium* sp.  | leaf of *Senecio flavus* (Asteraceae) | Al-Azhar University Egypt | Show antifungal activity and cytotoxic activity [116]                               |
| 363      | C_{30}H_{37}NO_{7} | 13                     | white amorphous powder    | *R. sanctae-cruciana* | leaves of the medicinal plant *A. lebbeck.* | India | Show considerable cytotoxic potential [117]                                        |
| 364      | C_{24}H_{30}O_{4} | 10                     | yellowish oil             | *Arthrinium arundinis* TE-3 | fresh leaves of cultivated tobacco | Hubei Province China | Show selective antifungal activity (364–365) Display moderate in vitro cytotoxicity (365) [118] |
| 365      | C_{20}H_{24}O_{4} | 9                      |                           |                   |            |                |                                                                                     |
| 366      | C_{20}H_{24}O_{3} | 9                      |                           |                   |            |                |                                                                                     |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|---------------------|------------------|------------|----------------|-------------------|-----|
| 367      | C\(_{23}\)H\(_{24}\)O\(_{5}\) | 12                     | brown powder        | *Aspergillus flavipes* Y-62 | stems of plant *Suaeda glauca* (Bunge) Bunge | Zhejiang province, East China | Show weak antimicrobial activity | [119] |
| 368      | C\(_{16}\)H\(_{14}\)O\(_{6}\) | 9                      | colorless crystals  | *Mycosphaerella* sp. (UFMGC2032) | healthy leaves of *Eugenia bimarginata* | Atlanta, GA, USA | Exhibit moderate antifungal activities | [120] |
| 369      | C\(_{17}\)H\(_{19}\)O\(_{9}\) | 9                      | colorless solid     |                   |            |                |                   |     |
| 370      | C\(_{20}\)H\(_{16}\)O\(_{5}\) | 13                     | off-white gum       | *Anteaglonium* sp. FL0768 | Living photosynthetic tissue of sand spikemoss (*Selaginella arenicola*; Selaginellaceae) |                |                   |     |
| 371      | C\(_{28}\)H\(_{26}\)N\(_{2}\)O\(_{5}\) | 17                     | amorphous light yellow powder | *Penicillium janthinellum* SYPF 7899 | three-year-old healthy *P. notoginseng* | Yunnan province, China | Exhibit significant inhibitory activities (371–373) | [122] |
| 372      | C\(_{13}\)H\(_{19}\)NO\(_{6}\) | 7                      | brown oil           |                   |            |                |                   |     |
| 373      | C\(_{14}\)H\(_{23}\)O\(_{4}\) | 3                      | colorless oil       | *Phaeophleospora vochysiae* sp. nov | *Vochysia divergens* | wetland in Brazil | Show considerable antimicrobial activity | [123] |
| 374      | C\(_{12}\)H\(_{17}\)NO\(_{6}\) | 5                      | colorless oil       | *Bionectria* sp. | fresh seeds of *R. teadigera* | Haut Plateaux region, Cameroon |                |     |
| 375      | C\(_{18}\)H\(_{14}\)N\(_{2}\)O\(_{6}\) | 13                     | white powder        |                   |            |                |                   |     |
| 376      | C\(_{13}\)H\(_{19}\)NO\(_{4}\) | 5                      | yellowish oil       | *Trichoderma atroviride* S361 | bark of *Cephalotaxus fortunei* | Zhejiang province, China |                |     |
| 377      | C\(_{18}\)H\(_{20}\)O\(_{7}\) | 9                      | amorphous powder    |                   |            |                |                   |     |
| 378      | C\(_{12}\)H\(_{10}\)O\(_{5}\) | 8                      | colorless oil       | *Xylaria* sp. SYPF 8246 | root of *Panax notoginseng* | Wenshan, Yunnan, China | Display significant inhibitory activities against human carboxylesterase 2 (hCE 2) (379,383–385) | [94] |
| 379      | C\(_{12}\)H\(_{18}\)O\(_{6}\) | 4                      |                     |                   |            |                |                   |     |
| 380      | C\(_{12}\)H\(_{20}\)O\(_{5}\) | 3                      |                     |                   |            |                |                   |     |
| 381      | C\(_{19}\)H\(_{22}\)O\(_{7}\) | 9                      |                     |                   |            |                |                   |     |
| 382      | C\(_{19}\)H\(_{21}\)O\(_{7}\)Cl | 9                      |                     |                   |            |                |                   |     |
| 383      | C\(_{18}\)H\(_{19}\)O\(_{7}\)Cl | 9                      |                     |                   |            |                |                   |     |
Table 1. Cont.

| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|-------------------|------------------------|----------------------|-------------------|------------|-----------------|---------------------|------|
| 386      | C_{32}H_{42}O_{4}  | 12                     | brown oil            | Byssochlamys spectabilis | leaf tissue of the medicinal plant Edgeworthia chrysantha | Zhejiang Province, China | weakly active against Escherichia coli and Staphylococcus aureus (388) | [124] |
| 387      | C_{16}H_{22}O_{3} | 7                      |                      |                   |            |                 | Display selective inhibitory effects toward hCE2-mediated FD hydrolysis (386) |      |
| 388      | C_{16}H_{26}O_{2} | 5                      | yellow oil           |                   |            |                 |                     |      |
| 389      | C_{20}H_{29}N_{5}O_{6} | 9                   | white amorphous powder | Fusarium chlamydosporium | Anvillea garcinii (Burm.f.) DC. leaves | Egypt | Exhibit selective antifungal activity and cytotoxic effect possess high antibacterial potential | [125] |
| 390      | C_{15}H_{16}N_{2}O_{2} | 9                 | red seaweed Bostrychia radicans | Annulohypoxylon stygium |            | Ubatuba city, São Paulo State, Brazil |                     | [126] |
| 391      | C_{23}H_{16}O_{2}N_{2} | 17                | purple-red powder    | Alternaria alternata Shm-1 | fresh wild body of Phellinus igniarius | Shanxi Province, China |                     | [127] |
| 392      | C_{10}H_{12}O_{6}  | 5                      | colorless crystals   |                   |            |                 |                     |      |
| 393      | C_{10}H_{14}N_{2}O_{2} | 5                  | yellow powder        | Cladosporium sp. JS1–2 | mangrove Ceriops tagal | Hainan Province in China | Show moderate antibacterial activities (392–393) Showed growth inhibition activities against newly hatched larvae of H. armigera Hubner (392–393) | [128] |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 394      | C₈H₁₃NO₄        | 3                      | white solid          | Diaporthe vochysiae sp. nov. (LMGF1583) | medicinal plant Vochysia divergens | | Display considerable antibacterial activity (395) | [129] |
| 395      | C₁₁H₁₇NO₄       | 4                      | white solid          | Diaporthe lithocarpus A740 | Twigs of medicinal plant Morinda officinalis | Guangdong province, China | Show low to moderate cytotoxic activity (394–395) | [41] |
| 396      | C₂₈H₄₀O₆        | 9                      | yellow oil           | Diaporthe lithocarpus A740 | Twigs of medicinal plant Morinda officinalis | Guangdong province, China | Show weak cytotoxic activity (396–397) | [41] |
| 397      | C₂₈H₄₀O₆        | 9                      | light yellow liquid  | Lasiosdiplodia pseudotheobromae | leaves of the mangrove plant Kandelia candel | Guangxi Province, China | Exhibite XO inhibition (407) oxidized form of 406 show high XO inhibition | [133] |
| 398      | C₃₀H₃₇O₇N      | 13                     | colorless powder     | Xylaria longipes | | Ailao Moutain | | [130] |
| 399      | C₃₀H₃₉O₉N      | 12                     | | | | | | |
| 400      | C₃₂H₄₁O₈N      | 13                     | | | | | | |
| 401      | C₃₀H₃₇NO₇      | 13                     | | | | | | |
| 402      | C₃₀H₃₇NO₇      | 13                     | | | | | | |
| 403      | C₈H₁₈O₇        | 10                     | | | | | | |
| 404      | C₁₁H₁₁ClO₅     | 6                      | | | | | | |
| 405      | C₁₂H₁₃ClO₄     | 6                      | | | | | | |
| 406      | C₇H₁₂O₃        | 2                      | | | | | | |
| 407      | C₁₃H₂₂O₃       | 3                      | light yellow liquid  | Lasiosdiplodia pseudotheobromae | | | | |
| 408      | C₁₇H₁₆O₈       | 10                     | pale-yellow needles  | Pleosporales sp. SK7 | leaves of the mangrove plant Kandelia candel | Guangxi Province, China | | [23] |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|-----|
| 409      | C_{15}H_{19}N_{2}O_{2} | 8                      | faint yellow oil     | *Aspergillus* sp. AV-2 | inner healthy leaves of mangrove plant *Avicennia marina* | Hurghada, Egypt |                       | [134] |
| 410      | C_{19}H_{22}O_{5}   | 9                      | yellow powder        |                   |            |                |                     |     |
| 411      | C_{10}H_{14}O_{3}   | 4                      | yellow oil           |                   |            |                |                     |     |
| 412      | C_{10}H_{14}O_{3}   | 4                      | yellowish oil        | *Irpex lacteus* DR10-1 | Roots of waterlogging tolerant plant *Distylium chinense* | Chongqing in the TGR area, China | Exhibit strong antioxidant activity (413) | [24] |
|          |                   |                        |                      |                   |            |                | Show moderate antibacterial activity (411–413) |     |
| 413      | C_{12}H_{16}O_{4}   | 5                      | brown flaky solid    |                   |            |                |                     |     |
| 414      | C_{33}H_{50}O_{6}   | 9                      | pale yellow oil      | *Penicillium crustosum* PRB-2 & *Xylaria* sp. HDN13-249 | *Xylaria* sp. HDN13-249: root of *Sonneratia caseolaris* | Hainan province, China | Show antibacterial activity (415–416) | [135] |
|          |                   |                        |                      |                   |            |                | Show promising activity against *M. phlei* (416) |     |
| 415      | C_{33}H_{50}O_{5}S  | 9                      | pale yellow oil      |                   |            |                |                     |     |
| 416      | C_{24}H_{40}O_{5}   | 5                      | pale yellow oil      | *Xylaria* sp. HDN13-249 |                   |                |                     |     |
| 417      | C_{24}H_{40}O_{5}S  | 5                      | pale yellow oils     |                   |            |                |                     |     |
| 418      | C_{9}H_{14}O_{2}    | 3                      | colorless oil        | *Aspergillus terreus* EN-539 & *Paecilomyces lilacinus* EN-531 | inner tissues of the marine red alga *Laurencia okamurae* | China | Exhibit inhibitory activity against bacteria and fungi | [136] |
| 419      | C_{23}H_{26}O_{5}   | 14                     | white powder         | *Diaporthe lithocarpus* | leaves of *Artocarpus heterophyllus* | Dortmund, Germany |                     | [137] |
| 420      | C_{16}H_{20}N_{2}O_{4} | 8                      | colourless oil       | *Aspergillus aculeatus* F027 | fresh leaves of *Ophiopogon japonicus* (Linn. f.) Ker-Gawl | Hubei province of China |                     | [138] |
| 421      | C_{17}H_{20}O_{6}   | 8                      | reddish oil          |                   |            |                |                     |     |
| 422      | C_{17}H_{20}O_{6}   | 8                      | yellow oil           |                   |            |                |                     |     |
| 423      | C_{15}H_{18}O_{5}   | 7                      | reddish oil          |                   |            |                |                     |     |
| 424      | C_{15}H_{18}O_{5}   | 7                      | pale-yellow oil      |                   |            |                |                     |     |

Table 1. Cont.
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity | Ref. |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|---------------------|------|
| 425      | C\textsubscript{16}H\textsubscript{20}O\textsubscript{5} | 7                      | amorphous powder     | *Hypoxylon fuscum* | lichen *Usnea* sp. | Lulong Snow Mountain in Lijiang, Yunnan, China | Exhibit moderate cytotoxicity (426–427) | [86] |
| 426      | C\textsubscript{21}H\textsubscript{26}O\textsubscript{6} | 4                      | white solid          |                   |            |                |                     |      |
| 427      | C\textsubscript{18}H\textsubscript{30}O\textsubscript{7} | 4                      | white powder         |                   |            |                |                     |      |
| 428      | C\textsubscript{18}H\textsubscript{28}O\textsubscript{6} | 5                      |                      |                   |            |                |                     |      |
| 429      | C\textsubscript{25}H\textsubscript{24}O\textsubscript{6} | 14                     | colorless gum        | *Simplicillium lanosonivum* (J.F.H. Beyma) Zare & W. Gams PSU-H168 and PSU-H261 | leaves of *Hevea brasiliensis* | Songkhla Province, Thailand | Exhibit antibacterial activity (430) Display antifungal activity (430–431) | [96] |
| 430      | C\textsubscript{32}H\textsubscript{33}O\textsubscript{8} | 16                     |                      |                   |            |                |                     |      |
| 431      | C\textsubscript{16}H\textsubscript{14}O\textsubscript{7} | 10                     | yellow gum           |                   |            |                |                     |      |
| 432      | C\textsubscript{14}H\textsubscript{20}O\textsubscript{4} | 5                      | white amorphous powder | *Clonostachys rosea* BS-2 | mangrove plants | Garut, Indonesia | Exhibit phytotoxicity against lettuce seedlings (432) | [140] |
| 433      | C\textsubscript{7}H\textsubscript{10}O\textsubscript{3} | 3                      | colourless oil       |                   |            |                |                     |      |
| 434      | C\textsubscript{9}H\textsubscript{12}O\textsubscript{3} | 4                      | white amorphous powder |                   |            |                |                     |      |
| 435      | C\textsubscript{9}H\textsubscript{14}O\textsubscript{4} | 3                      |                      |                   |            |                |                     |      |
| 436      | C\textsubscript{26}H\textsubscript{32}O\textsubscript{12} | 11                     | white powder         |                   |            |                |                     |      |
| 437      | C\textsubscript{26}H\textsubscript{38}O\textsubscript{11} | 8                      | white powder         |                   |            |                |                     |      |
| 438      | C\textsubscript{27}H\textsubscript{32}O\textsubscript{8} | 14                     | white powders        | *Talaromyces purpureus* | fresh leaves of the toxic medicinal plant *Tylophora ovata* | Guangxi Province, China | Show significant inhibitory activity against NO production in LPS-induced RAW264.7 cells (436) Show moderate inhibitory activities toward XOD and PTP1b (437,441) | [87] |
| 439      | C\textsubscript{29}H\textsubscript{40}O\textsubscript{9} | 10                     |                      |                   |            |                |                     |      |
| 440      | C\textsubscript{27}H\textsubscript{40}O\textsubscript{7} | 8                      |                      |                   |            |                |                     |      |
| 441      | C\textsubscript{26}H\textsubscript{34}O\textsubscript{7} | 10                     |                      |                   |            |                |                     |      |
| Compound | Molecular Formula | Degree of Unsaturation | Color and Morphology | Endophytic Fungus | Host Plant | Site and Nation | Biological Activity |
|----------|------------------|------------------------|----------------------|-------------------|------------|----------------|-------------------|
| 442      | C_{22}H_{32}N_{4}O_{5} | 9                      | white powder         | Phomopsis sp. D15a2a | leaves of Alternanthera bettzickiana (Amaranthaceae) | Anambra state of Nigeria | [55] |
| 443      | C_{4}H_{13}NO_{5}   | 3                      |                      |                   |            |                |                   |
| 444      | C_{20}H_{38}O_{7}   | 2                      | colorless oil        | Aureobasidium pullulans AJF1 | flower of Aconitum carmichaeli, Jangbaek Mountain, Gangwon-do, Korea | [141] |
| 445      | C_{30}H_{56}O_{10}  | 3                      |                      |                   |            |                |                   |
| 446      | C_{16}H_{14}O_{8}   | 10                     | yellow amorphous powder | Alternaria alternata JS0515 | Vitex rotundifolia (beach vitex) | Suncheon, Korea | [142] |
| 447      | C_{23}H_{27}O_{5}Cl | 10                     | colorless oil        |                   |            |                |                   |
| 448      | C_{10}H_{10}O_{4}   | 6                      | white amorphous powder | Armillaria sp. & Epicoccum sp. YUD17002 | YUD17002: rhizomes of the underground portion of Gastrodia elata | Yunnan Province, China | Exhibit moderate in vitro cytotoxic activities (447) Show weak acetylcholinesterase inhibitory activity (447) [27] |
| 449      | C_{14}H_{20}O_{9}   | 5                      | light-yellow oil     |                   |            |                |                   |
4. Conclusions

From 2017–2019, a total of 449 new secondary metabolites isolated from plant endophytic fungi using different culture methods like common culture, co-culture with bacteria, addition of metal ions and so on, were summarized in this review. These compounds have a variety of unique structures, the difference in structure leads to various biological activities of these compounds. Some of these metabolites display significant antimicrobial effects, cytotoxic activities, antioxidant activities and other biological activities, which indicate that they have potential to be agents to treat some diseases. In this review, structure-activity relationships of some compounds were also reviewed.

According to genome sequencing, a lot of microorganisms have the potential to produce secondary metabolites with novel structures. However, many fungal gene clusters may be silent under standard laboratory growth conditions. As a result, some pathways to yield secondary metabolites cannot be expressed. Therefore, activating these pathways means that we can get more novel compounds. The approach of microorganism co-culture, involving the cultivation of two or more microorganisms in the same lab environment can do a favour for us. Interestingly, 29 new compounds summarized above were obtained through co-culture of bacteria and fungi or two fungi. Besides, by adding CuCl$_2$ into fermentation medium of an endophytic fungus \textit{P. citrinum} 46, two compounds were isolated. The results showed that adding Cu$^{2+}$ into medium to activate silent fungal metabolic pathways can increase the discovery of new compounds.

Because the compounds mentioned above were isolated from endophytic fungi in different parts of different plants in different regions, they have a variety of structures and biological activities. In addition to anti-tumor and anti-microbial activities, some compounds also exhibit unique biological activities. Among them, 7 compounds showed weak to moderate AChE inhibitory activity. Some compounds exhibited moderate to potent $\alpha$-glucosidase inhibitory activity compared with those of positive control. By using adapted 2,2$'${-diphenyl-b-picrylhydrazyl (DPPH) method, a few of compounds were found to show moderate to remarkable antioxidant activity. Some of them also showed weak to significant inhibitory activity against NO production in LPS-induced RAW264.7 cells. The biological activity properties of 18 compounds were evaluated for inhibitory activity against some enzymes like pancreatic lipase, the 5-lipoxygenase (5-LOX), the Indoleamine 2,3-dioxygenase (IDO), Mycobacterium tuberculosis protein tyrosine phosphatase B (MptPb), the xanthine oxidase (XO) and so on, they showed weak to high inhibition.

Endophytic fungi isolated from different parts of plants are a huge treasure house on account of the discovery of novel secondary metabolites with biological activities and unique structures. Since the endophyte resources were discovered, more and more researches have been conducted on them. Just from my review article, the new secondary metabolites isolated from plant endophytes during the three years from 2017 to 2019 were counted. Among them, 38 articles were published in 2017, 136 new compounds were obtained; 39 articles were published in 2018, 117 new compounds were obtained; 57 articles were published in 2019, and 196 new compounds were obtained. It can be discovered that in the past three years, the research trend of plant endophytes and their metabolites have increased year by year. The more new compounds obtained, the greater the possibility of screening compounds with excellent biological activity. This is also an important significance for researchers to study plant endophytes. Through this review, i hope to arouse more people’s interest and attention in this field and screen out compounds with good biological activities to create a better life for mankind by utilizing endophytes resources.

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