Review

Naturally Occurring Isocoumarins Derivatives from Endophytic Fungi: Sources, Isolation, Structural Characterization, Biosynthesis, and Biological Activities

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Abstract: Recently, the metabolites separated from endophytes have attracted significant attention, as many of them have a unique structure and appealing pharmacological and biological potentials. Isocoumarins represent one of the most interesting classes of metabolites, which are coumarins isomers with a reversed lactone moiety. They are produced by plants, microbes, marine organisms, bacteria, insects, liverworts, and fungi and possessed a wide array of bioactivities. This review gives an overview of isocoumarins derivatives from endophytic fungi and their source, isolation, structural characterization, biosynthesis, and bioactivities, concentrating on the period from 2000 to 2019. Overall, 307 metabolites and more than 120 references are conferred. This is the first review on these multi-faceted metabolites from endophytic fungi.

Keywords: endophytes; isocoumarins; dihydroisocoumarins; biosynthesis; biological activities

1. Introduction

The search for new metabolites for the agrochemical and pharmaceutical industries is an on-going work that needs continual optimization. Fungi are eukaryotic microorganisms that reside in almost all environmental types in nature where they have key roles in preserving the ecological balance [1,2]. Endophytes primarily inhabit their hosts without causing any harm to the hosts [3–6]. These endophytic fungi have played pivotal roles in their host’s survival through supplying nutrients and producing plenty of bioactive metabolites to prevent the danger of phytopathogenic bacteria on the host [7,8]. Endophytic fungi have gained loads of attention in natural products chemistry field due to their sustainability to biosynthesize structurally diverse and bioactive molecules, some of which are important agrochemicals and pharmaceuticals [9,10]. Isocoumarins (1H-2-benzopyran-1-ones or isochromene derivatives) are a class of biosynthetically, structurally, and pharmacologically intriguing natural products, which
are coumarins isomers with a reversed lactone moiety that could possess 6,8-dioxygenated pattern, 3-(un)substituted phenyl ring or 3-alkyl chain (C\textsubscript{1}-C\textsubscript{17}) \[11,12\]. The oxygenation could exist at one or more of the six free positions of the isocoumarin skeleton. The oxygen atoms may be in the form of ethereal, phenolic, or glycosidic functionalities. Additionally, C-3 substituents are found more commonly on both natural and synthetic isocoumarins derivatives. Substituents that exist on the isocoumarin ring may involve alkyl, halogen, heterocyclic, aryl, or other groups \[13\]. Furthermore, the saturation of C-3/C-4 in isocoumarins will give 3,4-dihydroisocoumarins (DHICs) analogs (Figure 1).

Moreover, isocoumarins and DHICs possess a close relation with isochromans, they are known as isochromen-1-one and isochroman-1-ones, respectively, since the C-1 active methylene in isochromans can be easily oxidized to the related isocoumarins derivatives. Most of the natural isocoumarins and DHICs are given trivial names, which are derived mainly from the name of the species or genus of the host organisms. They have been reported from a broad scope of natural sources, including plants, microbes, marine organisms, bacteria, insects, liverworts, and fungi (e.g., soil, endophytic, and marine fungi) \[14,15\]. Isocoumarins are considered as important intermediates in the synthesis of a wide range of carbo- and heterocyclic compounds such as isoquinolines, isochromenes, and different aromatic compounds \[16\]. Thus, isocoumarin framework has been explored in various areas, including drug discovery, pharmaceutical and medicinal chemistry, and organic synthesis \[13\]. It has been reported that these metabolites possess various bioactivities: antimicrobial, cytotoxic, algicidal, antiallergic, immunomodulatory, antimalarial, plant growth regulatory, and acetylcholinesterase and protease inhibitors \[11,17–20\]. This review aims to give a highlight on the naturally occurring isocoumarins derivatives reported from endophytic fungi, focusing on the period from 2000 to July 2019. Herein, 307 naturally occurring isocoumarins derivatives have been listed most of them are reported from *Aspergillus* and *Penicillium* genera (Figure 2).
Figure 2. Distribution of isocoumarin derivatives in different fungal genus.

The reported fungal isocoumarin derivatives are drawn according to their similarity in the isocoumarin skeleton, as well as nomenclature (Figures 3–30).
Figure 3. Structures of isocoumarin derivatives 1–16.
Figure 4. Structures of isocoumarin derivatives 17–33.

| \( R_1 \) | \( R_2 \) | \( R_3 \) | \( R_4 \) | \( R_5 \) | Name                           |
|-------|-------|-------|-------|-------|-----------------|
| \( \text{H} \) | \( \text{CH}_3 \) | \( \text{H} \) | \( \text{OH} \) | \( \text{OH} \) | \( 3R \)-7-Hydroxy-5-methylmellein (17) |
| \( \text{H} \) | \( \text{OH} \) | \( \text{COOCH}_3 \) | \( \text{H} \) | \( \text{H} \) | Akolitserin (18) |
| \( \text{H} \) | \( \text{COOCH}_3 \) | \( \text{H} \) | \( \text{H} \) | \( \text{OH} \) | \( \text{(-)}\-(R)\-5\-(Methoxycarbonyl)mellein (19) \) |
| \( \text{CH}_3 \) | \( \text{H} \) | \( \text{OH} \) | \( \text{CH}_3 \) | \( \text{OH} \) | \( 3R^*,4S^*\)-6,8-Dihydroxy-3,4,7-trimethylisocoumarin (20) |
| \( \text{CH}_3 \) | \( \text{CH}_3 \) | \( \text{OH} \) | \( \text{CH}_3 \) | \( \text{OH} \) | \( 3R,4S\)-6,8-Dihydroxy-3,4,5,7-tetramethylisochroman (21) |
| \( \text{OH} \) | \( \text{Cl} \) | \( \text{OH} \) | \( \text{H} \) | \( \text{OH} \) | \( 3R,4R\)-5-Chloro-4,6-dihydroxymellein (22) |
| \( \text{H} \) | \( \text{Br} \) | \( \text{OH} \) | \( \text{H} \) | \( \text{OCH}_3 \) | Palmaerone A (23) |
| \( \text{H} \) | \( \text{H} \) | \( \text{OH} \) | \( \text{Br} \) | \( \text{OCH}_3 \) | Palmaerone B (24) |
| \( \text{H} \) | \( \text{H} \) | \( \text{OCH}_3 \) | \( \text{Br} \) | \( \text{OCH}_3 \) | Palmaerone C (25) |
| \( \text{H} \) | \( \text{H} \) | \( \text{OH} \) | \( \text{Br} \) | \( \text{OH} \) | Palmaerone D (26) |
| \( \text{H} \) | \( \text{Br} \) | \( \text{OH} \) | \( \text{OH} \) | \( \text{OCH}_3 \) | Palmaerone E (27) |
| \( \text{H} \) | \( \text{Cl} \) | \( \text{OH} \) | \( \text{H} \) | \( \text{OCH}_3 \) | Palmaerone F (28) |
| \( \text{H} \) | \( \text{H} \) | \( \text{OH} \) | \( \text{Cl} \) | \( \text{OCH}_3 \) | Palmaerone G (29) |
| \( \text{H} \) | \( \text{Cl} \) | \( \text{OH} \) | \( \text{H} \) | \( \text{OH} \) | \( R \)-5-Chloro-6-hydroxymellein (30) |
| \( \text{H} \) | \( \text{Cl} \) | \( \text{OH} \) | \( \text{Cl} \) | \( \text{OCH}_3 \) | Palmaerin A (31) |
| \( \text{H} \) | \( \text{Br} \) | \( \text{OH} \) | \( \text{Br} \) | \( \text{OH} \) | Palmaerin B (32) |
| \( \text{H} \) | \( \text{Br} \) | \( \text{OH} \) | \( \text{H} \) | \( \text{OH} \) | Palmaerin D (33) |
Figure 5. Structures of isocoumarin derivatives 34–44.

| R₁ | R₂ | R₃ | R₄ | R₅          |
|----|----|----|----|-------------|
| ⋯OH| COOH| OH | H  | H           |
| H  | H  | H  | H  | OH          | (3R,4R)-3,4-Dihydro-4,6-dihydroxy-3-methyl-1-oxo-1H-isochromene-5-carboxylic acid (34) |
| H  | H  | H  | OH | OH          | (R)-7-Hydroxymellein (36) |
| ⋯OH| H  | H  | O₈ | OH          | (3R,4R)-4,7-Dihydroxymellein (37) |
| H  | H  | OH | A  | OH          | Angelicoin A (38) |
| H  | H  | OH | CHO| OH          | Periplanetin A (39) |
| H  | H  | CH₂OH| OCH₃| OH         | (3R)-Methyl-8-hydroxy-6-(hydroxymethyl)-7-methoxydihydroisocoumarin (40) |
| H  | H  | CH₂OH| OCH₃| OCH₃       | (3R)-Methyl-7,8-dimethoxy-6-(hydroxymethyl)-dihydroisocoumarin (41) |
| H  | H  | OH  | H  | OH          | (R)-6-Hydroxymellein (42) |
| H  | H  | OCH₃| H  | OCH₃        | 6,8-Dimethoxy-3-methyl-3,4-dihydro-1H-isochromen-1-one (43) |
| H  | H  | OH  | CH₃| OH          | Periplanetin B (44) |
Figure 6. Structures of isocoumarin derivatives 45–53.

![Diagram of isocoumarin derivatives](image)

| R₁ | R₂      | R₃   | R₄   | R₅   | Structures                                      |
|----|---------|------|------|------|------------------------------------------------|
| H  | CH₂OCOCH₃ | H    | H    | OH   | Arundinone A (45)                               |
| H  | H       | COOH | OH   | OH   | Aspergillspin F (46)                            |
| H  | COOCH₃  | H    | H    | OH   | (3R)-5-Carbomethoxymellein (47)                 |
| H  | CHO     | H    | H    | OH   | (3R)-5-Formylmellein (48)                       |
| ···OH | COOCH₃  | H    | H    | OH   | Xylarellein (49)                                |
| H  | COOH    | H    | H    | OH   | (3R)-5-Carboxylmellein (50)                     |
| ⬅️CH₃ | H       | H    | CH₂OH| OH   | Gamahorin (51)                                  |
| H  | A       | OCH₃ | H    | OCH₃ | Versicoumarin B (52)                            |
| H  | A       | OCH₃ | OH   | H    | Versicoumarin C (53)                            |
Figure 7. Structures of isocoumarin derivatives 54–66.
Figure 8. Structures of isocoumarin derivatives 67–82.
Figure 9. Structures of isocoumarin derivatives 83–96.

| R₁ | R₂ | R₃ | R₄ | R₅ | R₆          | Name                                                                 |
|----|----|----|----|----|-------------|----------------------------------------------------------------------|
| CH₃| H  | H  | H  | H  | OH          | 3-Methyl-8-hydroxyisocoumarin (83)                                   |
| CH₃| H  | OCH₃| OH | H  | OH          | 6,8-Dihydroxy-5-methoxy-3-methyl-1H-isochromen-1-one (84)            |
| H  | COCH₂OH| H | OCH₃| H  | OH          | Myrothelactone C (85)                                                |
| CH₃| COOH| H  | OCH₃| H  | OH          | Myrothelactone D (86)                                                |
| CH₂OH| CH₂OH| H | OCH₃| H  | OH          | Tubakialactone B (87)                                                |
| CH₃| H  | H  | H  | OH | H           | Saccharonol A (88)                                                   |
| CH₃| H  | H  | OH | CH₃| OH          | Similanpyrone B (89)                                                 |
| CH₃| H  | H  | OH | OCH₃| OH          | Reticulol (90)                                                       |
| CH₃| CH₂OH| H | OH | H  | OCH₃        | 6-Hydroxy-4-hydroxymethyl-8-methoxy-3-methylisocoumarin (91)         |
| CH₃| CH₃ | H  | OH | H  | OCH₃        | 6-Hydroxy-8-methoxy-3,4-dimethylisocoumarin (92)                     |
| CH₃| CH₃ | H  | OH | H  | OH          | 3,4-Dimethyl-6,8-dihydroxyisocoumarin (93)                           |
| CH₃| CH₂OH| H | OH | H  | OCH₃        | 6-Hydroxy-4-hydroxymethyl-8-methoxy-3-methyl-isocoumarin (94)        |
| CH₃| CH₂OH| H | OH | H  | OH          | Sescandelin B (95)                                                   |
| CH₂OH| H   | H  | OH | H  | OCH₃        | 6-Hydroxy-3-hydroxymethyl-8-methoxyisocoumarin (96)                  |
Figure 10. Structures of isocoumarin derivatives 97–105.

| R₁    | R₂    | R₃    | R₄    | R₅    | R₆    |
|-------|-------|-------|-------|-------|-------|
| CH₂OH | H     | H     | OH    | H     | OH    |
| COOCH₃| H     | CH₃   | OH    | CH₃   | OH    |
| COOH  | H     | CH₃   | OH    | COOCH₃| OH    |
| COOH  | H     | H     | OH    | H     | OH    |
| CH₃   | CH₃   | H     | OH    | CH₃   | OH    |
| CH₃   | CH₃   | H     | OH    | CH₃   | OH    |
| CH₃   | H     | H     | OCH₃  | OCH₃  | OH    |
| CH₃   | H     | CH₃   | H     | OH    | H     |
| CH₂OH | H     | H     | OH    | H     | OH    |

4,6-Dihydroxy-3,9-dehydromellein (97)
Banksiamarin A (98)
Banksiamarin B (99)
6,8-Dihydroxyisocoumarin-3-carboxylic acid (100)
Nectriapryone A (101)
Nectriapryone B (102)
6-O-Methylreticulol (103)
7-Hydroxy-3,5-dimethylisoschoren-1-one (104)
6,8-Dihydroxy-3-hydroxy methylisocoumarin (105)

Figure 11. Structures of isocoumarin derivatives 106–113.
Figure 10. Structures of isocoumarin derivatives 97–105.

Figure 11. Structures of isocoumarin derivatives 106–113.

| Structure | Formula | Description |
|-----------|---------|-------------|
| Botryospyrone A (106) | CH₃ H CH₃ OH OH OH | |
| Botryospyrone B (107) | CH₃ H OCH₃ OCH₃ H OH | |
| Decarboxyhydroxycitrinone (108) | CH₂OH CH₃ CH₃ OH H OH | |
| Tubakialactone A (109) | CH₂OH CH₃ H OCH₃ H OH | |
| 6,8 Dihydroxy 7 methyl 1 oxo 1H isochromene-3-carboxylic acid (110) | COOH H H OH CH₃ OH | |
| Oryzaein A (111) | CH₂COCH₃ H CH₂(CH₂)₂OH H OH H | |
| Oryzaein B (112) | CH₂COCH₃ H CH₂(CH₂)₂OH H H OCH₃ | |
| Caudacoumarin C (113) | CH₂OH H A OCH₃ H H | |
Figure 12. Structures of isocoumarin derivatives 114–123.

- 4,5,7-Trihydroxy-3-methoxy-3,6-dimethylisochroman-1-one (114)
- 5,7-Dihydroxy-3-methoxy-3,6-dimethylisochromane-1,4-dione (115)
- 3,4-Dihydro-3,6,8-trihydroxy-3,5-dimethylisocoumarin (116)
- Tenuissimatasin (117)
- Penicoffrazin B (118)
- Penicoffrazin C (119)
- 6,8-Dihydroxy-3-methoxy-3,7-dimethylisochroman-1-one (120)

Figure 12. Structures of isocoumarin derivatives 114–123.
Figure 13. Structures of isocoumarin derivatives 124–136.
Figure 14. Structures of isocoumarin derivatives 137–149.
Figure 15. Structure of isocoumarin derivatives 150–159.

Figure 16. Structures of isocoumarin derivatives 160–164.
Figure 17. Structures of isocoumarin derivatives 165–174.
Figure 18. Structures of isocoumarin derivatives 175–182.

Figure 19. Structures of isocoumarin derivatives 183–187.
Figure 20. Structures of isocoumarin derivatives 188–200.
Figure 21. Structures of isocoumarin derivatives 201–211.
Figure 22. Structures of isocoumarin derivatives 212–228.

- Aspergillamarin A (212)
- Aspergillamarin B (213)
- Penicimarin B (214)
- Penicimarin C (215)
- (R)-3-[(R)-4,5-Dihydroxypentyl] 8-hydroxysochroman-1-one (216)
- 5,6-Dihydroxy-3-[(4-hydroxypentyl) isochroman-1-one (217)
- Maculansline C (218)
- Desmethyldiportinol (219)
- Dichlorodiportin (220)
- Desmethyldichlorodiportin (221)
- Peniisoumarin D (222)
- Peniisoumarin E (223)
- Peniisoumarin F (224)
- Peniisoumarin G (225)
- Peniisoumarin H (226)
- Peniisoumarin I (227)
- Peniisoumarin J (228)
Figure 23. Structures of isocoumarin derivatives 229–239.

| R<sub>1</sub> | R<sub>2</sub> | R<sub>3</sub> | R<sub>4</sub> | R<sub>5</sub> | R<sub>6</sub> | R<sub>7</sub> |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| H           | OCH<sub>3</sub> | H           | OH          | H           | OH          | CH<sub>Cl</sub> |
| H           | OCH<sub>3</sub> | H           | OH          | H           | OH          | CH<sub>3</sub> |
| H           | OCH<sub>3</sub> | H           | OH          | H           | OH          | CH<sub>2</sub>OH |
| CH<sub>3</sub> | CH<sub>3</sub> | OH          | H           | H           | OH          | CH<sub>3</sub> |
| H           | OCH<sub>3</sub> | H           | OH          | H           | OH          | CH<sub>3</sub> |
| H           | OH           | H           | OH          | H           | OH          | CH<sub>3</sub> |
| H           | OCH<sub>3</sub> | H           | OCH<sub>3</sub>| H           | OH          | CH<sub>Cl</sub> |
| H           | OCH<sub>3</sub> | H           | OCH<sub>3</sub>| H           | OH          | CH(OH)<sub>2</sub> |
| H           | OCH<sub>3</sub> | H           | OH          | OH          | OH          | CH<sub>2</sub>OH |
| H           | OCH<sub>3</sub> | H           | OH          | OH          | OH          | COOCH<sub>3</sub> |

3-[R]-3,3-Dichloro-2-hydroxypropyl]-8-hydroxy-6-methoxy-1H-isochromen-1-one (229)

(+)-Diaporthin (230)

Diaportinol (231)

(+)-(10R)-7-Hydroxy-3-(2-hydroxy-propyl)-5,6- dimethylisochromen-1-one (232)

Peyroisocoumarin D (233)

Orthosporin (234)

8-Methyl-11-chlorodiaporthin (235)

8-Methyl-11,11-dichlorodiaporthin (236)

8-Hydroxy-6-methoxy-3-(2,3,3-trihydroxypropyl)-1H-isochromen-1-one (237)

8-Hydroxy-6-methoxy-3-(1,2,3-trihydroxypropyl)-1H-isochromen-1-one (238)

Aspergisocoumin C (239)
Figure 24. Structures of isocoumarin derivatives 240–250.

\[
\begin{align*}
&\text{R}_1 \quad \text{R}_2 \quad \text{R}_3 \quad \text{R}_4 \quad \text{R}_5 \quad \text{R}_6 \quad \text{R}_7 \quad \text{R}_8 \\
&\text{HOH} \quad \text{H} \quad \text{OCH}_3 \quad \text{OCH}_3 \quad \text{OH} \quad \text{HOH} \quad \text{H} \quad \text{H} \\
&\text{H} \quad \text{CH}_3 \quad \text{OH} \quad \text{CH}_3 \quad \text{OH} \quad \text{H} \quad \text{OH} \quad \text{H} \\
&\text{H} \quad \text{CH}_3 \quad \text{OH} \quad \text{CH}_3 \quad \text{OH} \quad \text{H} \quad \text{H} \quad \text{OH} \\
&\text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{OCH}_3 \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\
&\text{H} \quad \text{OH} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \\
&\text{OH} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{H} \\
&\text{(3R,4R,10R)-Fusaretin 4-hydroxy-6,7-dimethyl ether (240)} \\
&\text{Colletomellein A (241)} \\
&\text{Colletomellein B (242)} \\
&\text{Peniciisocoumarin D (243)} \\
&\text{Peniciisocoumarin F (244)} \\
&\text{Peniciisocoumarin H (245)} \\
&\text{3.4-Dihydro-8-hydroxy-6-methoxy-(3R)-propylocoumarin (246)} \\
&\text{Peniciisocoumarin C (247)} \\
&\text{Peniciisocoumarin E (248)} \\
&\text{Peniciisocoumarin G (249)} \\
&\text{(R)-3-(3-Hydroxypropyl)-8-hydroxy-3,4-dihydroisocoumarin (250)}
\end{align*}
\]
Figure 25. Structures of isocoumarin derivatives 251–264.
Figure 26. Structures of isocoumarin derivatives 265–272.
Figure 27. Structures of isocoumarin derivatives 273–279.
Figure 28. Structures of isocoumarin derivatives 280–294.
Figure 29. Structures of isocoumarin derivatives 295–300.
2. Biosynthesis

Isocoumarin was originated of the acetate-malonate or the polyketide synthase (PKS) pathway [21,22]. Kurosaki et al. stated that 11 is biosynthesized from malonyl-CoA and acetyl-CoA...
through a pentaketide [23]. 3,4-Dihydro-6-hydroxymellein (III) is considered as an intermediate which would be transformed to 11 by O-methyltransferase which methylates the 6-OH group of the isocoumarin [23]. The loss of the OH group at C-6 gives rise to mellein [24]. A heptaketide II, a longer polyketone chain is implicated in 165 biosynthesis [25] (Figure 31).

Figure 31. Proposed biosynthetic pathway of 11, 35, 88, 90, and 165 [21,23–26].

Krohn et al. reported that the existence of a biosynthetic relationship between 56 and 125 [27]. They assumed that the open-chain precursor A can be directly closed to a six-membered lactone (pathway I) or cyclized after the side chain rotation through the acetyl enol tautomer to produce 56 (pathway II) [27] (Figure 32).

Figure 32. Proposed biosynthetic pathway of 56 and 125 [27].
It was postulated that 273 is also derived from the malonate-acetate pathway [28]. The pentaketide (I) cyclization and enolization produce 88. A Claisen condensation occurs between 88 and tetraketide (II) to yield III. The side chain enolization, along with the hemiketal formation by the side chain ketone carbonyl and C-6 phenolic OH of the isocoumarin nucleus, forms a hemiketal IV. Then, the ketal formation and methylation in the side chain by S-adenosyl methionine (SAM) yield V and finally 273 [28] (Figure 33).

Moreover, Song et al. reported that an intramolecular cyclization occurs of a polyketide chain (Path A, Figure 6) [22]. The C-4 substituted derivatives have been resulted from the participation of an additional carbon unit in the cyclization (Path B, Figure 34).

![Figure 33. Proposed biosynthetic pathway of 273 [28].](image)

![Figure 34. Proposed biosynthetic pathway of 70, 71, 138, 179, and 180 [22].](image)
Therefore, the rare isocoumarin derivatives, 179 and 180 biosynthesis differs from those of 70, 71, and 138, in which a carbon moiety (CH₂OH) from formate or serine took part in the cyclization. Additionally, the 3-unsubstituted derivatives couldn’t be yielded in the biosynthesis of compounds 138 and 70; due to the C-11 oxidation is usually taking place after the polyketide chain cyclization [22]. Chen et al. postulated the biosynthetic origin of 296, an isocoumarin-indole diketopiperazine alkaloid (Figure 35) [29].

![Proposed biosynthetic pathway of 235, 236, and 296](image)

6,8-Dihydroxy-3-(2-oxopropyl)-1H-isochromen-1-one (I) was originated from the PKS pathway. It was then chlorinated and O-methylated to produce 3-(3-chloro-2-oxopropyl)-6,8-dimethoxy-1H-isochromen-1-one (II) by the catalytic effect of a bifunctional hybrid enzyme (BFHEnz). The methyl-carbonyl group of II undergoes chlorination and reduction leading to the formation of 235 and 236, respectively. Then, the hybridization of the diketopiperazine and isocoumarin units by a free radical mechanism, which could be catalyzed by cytochrome P450 giving 296 [29].

3. Structural Characterization of Isocoumarins Derivatives

Isocoumarins can be characterized by different spectral techniques such as 1D (1H, 13C, and NOE) and 2D NMR techniques (COSY, HSQC, HMBC, ROESY, and NOESY) combined with other usual methods (chemical synthesis, UV, IR, MS, etc.). However, their spectral data cannot be generalized as the data differ to a wide range relying on the type, position, number, and nature of substituents connected to the core skeleton. Furthermore, these data vary basically due to the variation of the core ring. In the compounds having isocoumarins framework, the lactone carbonyl frequency generally appears in the region 1745–1700 cm⁻¹ in the IR. In 1H NMR, the C-3 vinylic proton appears at 6.2–7.0 ppm as a singlet or doublet for C₃-substituted and unsubstituted derivatives, respectively. In 13C NMR, the lactone C=O appears in the range from 164 ppm to 168 ppm. In the 3-substituted derivatives, C-4 vinylic proton appears at 6.11–6.7 ppm as a singlet. 3,4-Dihydroisocoumarins derivatives have relatively more complicated 1H NMR spectra than isocoumarins due to C-4 and C-3 vicinal coupling.
and/or C-4 diastereotopic protons geminal coupling. In both derivatives, the 8-OH group appears at 10.0–12.0 ppm due to the hydrogen bonding to the C-1 carbonyl.

Mass spectroscopy is a helpful tool for the identification of these metabolites. The existence of sulfur was evident by the intensity of [M + 2]+ ion peak (~4.5% of the molecular ion peak) [30]. Moreover, the chlorine atom in the structure was characterized by two ion peaks [M + H]+ and [M+2H]+ in a ratio 3:1 [31,32]. The relative configuration was determined by NOE, NOESY, and ROESY. The circular dichroism (CD) is usually utilized to assess the absolute configuration by comparison of the theoretical and experimental CD spectra [30,31,33]. Besides, the total synthesis provides important information and an additional confirmation for characterization of these metabolites structures. Furthermore, it allows the synthesis of analogs with improved biological efficiencies [11,34,35]. The X-ray structure crystallographic analysis of the crystalline derivatives is another tool for the absolute configuration determination. This technique could not be applied in many cases since the crystals with the required qualifications are not available because most of these metabolites do not crystallize conveniently [20,27,36]. Finally, the assignment of the absolute configuration could be done using Mosher’s method and the differences in chemical shift between the (R)- and (S)-MTPA were analyzed [33,37].

4. Methods of Extraction and Purification of Isocoumarins Derivatives

For the extraction and isolation of isocoumarins, the fungal material was extracted with CH$_2$Cl$_2$, acetone or EtOAc. The total extracts were partitioned between n-hexane, CHCl$_3$, EtOAc, and MeOH or fractionated on SiO$_2$ 60 VLC using mixtures of n-hexane, EtOAc, and MeOH, or using petroleum ether, CH$_2$Cl$_2$, and MeOH, respectively [38–40]. The fractions were chromatographed over Sephadex LH-20 (CHCl$_3$:MeOH 1:1), SiO$_2$ CC using gradient elution of CH$_2$Cl$_2$:MeOH; PE:EtOAc; n-hexane:EtoAc [31,36,37,41–43] or RP-18 CC using MeOH-H$_2$O (8:2, v/v) [33]. Purifications of compounds were achieved by preparative HPLC using gradient of MeOH:H$_2$O or MeCN:H$_2$O [31,39,40]; SiO$_2$ CC (n-hexane:acetone:MeOH, n-hexane:acetone gradient or benzene:EtOAc) [44–46]; RP-18 CC (H$_2$O:MeOH gradient) [47]. Preparative TLC could be used for compounds purification using acetone:petroleum ether (3:7) [41]; CHCl$_3$:Me$_2$CO:HCO$_2$H (97:3:0.01); petrol:CHCl$_3$ and CHCl$_3$:Me$_2$CO [48]; CH$_2$Cl$_2$:2-propanol (50:1) [49]; PE:EtOAc (1:1) [47]. Isocoumarins derivatives can be purified by recrystallization from CH$_2$Cl$_2$:CH$_3$OH or PE:EtOAc until they showed constant melting points. These compounds can be detected on TLC by UV light or spraying reagents (vanillin-sulfuric acid or cerium-molybdenum) [27].

5. Biological Activities

5.1. Antimicrobial Activity

The isocoumarins 4 and 5 which were produced by an unidentified Ascomycete, separated from Meliotus dentatus had a potent antibacterial effect toward B. megaterium and E. coli with equal partial inhibition (PI) 10 and 9 mm, respectively compared to penicillin (PI 18 and 14 mm, respectively) and tetracycline (PI 18 and 18 mm, respectively). Furthermore, 4 and 5 exhibited prominent antifungal activities toward Botrytis cinerea, Microbotryum violaceum, and Septoria tritici and algicidal activities towards Chlorella fusca [50]. Compound 6 was tested against C. fusca, E. coli, B. megaterium, and M. violaceum using agar diffusion assay. It showed activity against C. fusca (IZD 9 mm), compared to actidione (IZD 35 mm) as well as against B. megaterium and M. violaceum with IZDs 8 and 6 mm, respectively [43]. Oliveira et al. indicated that 6 exhibited antifungal potential towards Cladosporium sphaerospermum and C. cladosporioides with detection limit 10 and 5 µg, respectively, whereas 3 showed moderate activity with detection limit 10 and 25 µg, respectively [18]. However, 8 was inactive [18]. The new isocoumarins 23–29 produced by Lachnum palmae associated with Przewalskia tanguita showed antimicrobial activities against Penicillium sp., C. neoformans, C. albicans, S. aureus, and B. subtilis (MICs 10–75 µg/mL), compared to kanamycin and amphotericin B using broth microdilution assay.
It is noteworthy that 27 had potential antimicrobial potentials towards all the strains tested (MICs 10–55 µg/mL) [51]. The antifungal effect of 34 separated from Xylaria sp. and 36 and 37 separated from Penicillium sp. towards Cladosporium cladosporioides and C. sphaerospermum was assessed using direct bioautography assay [17]. Compounds 37 and 36 showed a promising effect against C. sphaerospermum and C. cladosporioides (MICs 10.0 and 5.00 µg, respectively), compared to nystatin (MICs 1.0 and 1.0 µg, respectively), while 34 had moderate effect towards C. sphaerospermum and C. cladosporioides (MICs 25.0 and 10.0 µg, respectively) [17]. Furthermore, compound 65 exhibited moderate effect towards Vibrio parahaemolyticus and B. cereus with MICs 6.25 µM [52]. Furthermore, 35 exhibited only weak potential towards Botrytis cinerea (EC$_{50}$ 49.2 µg/mL) [53]. However, 78 and 79 showed no antifungal activity (Conc. 128 µg/mL) toward C. albicans (ATCC10231 and ATCC32354) [54]. Compounds 59, 116, 124, and 125 were tested against three fungal organisms: Eurotiurn repens, Mycoctypha rnicospora, and Ustilagio violaceae. Only 59 had a moderate potential towards all tested fungi [20]. Compound 132 was evaluated for the antimicrobial effect towards Cladosporium herbarum, Aspergillus niger, B. subtilis, and Pseudomonas syringae. The results revealed that 132 exhibited only mild activity towards B. subtilis with MIC 25 µg/mL, compared to chloramphenicol (MIC 3.13 µg/mL) [55]. The dihydroisocoumarins 154 and 155 showed selective antibacterial potential against the five pathogenic bacteria S. epidermidis, B. cereus, S. aureus, Vibrio alginolyticus, and E. coli (MICs 20, 20, 20, 20, and 20 µM, respectively for 154 and 10, 20, 20, 20, and 20 µM, respectively for 155), compared to ciprofloxacin (MICs 0.30, 0.30, 1.20, 0.60, and 1.25 µM, respectively) [56]. The antibacterial activities of 188, 189, and 193 were tested against B. megaterium, B. subtilis, E. coli, Micrococcus tetragenus, Clostridium perfringens, and MRSA S. aureus. Compound 189 had a stronger antibacterial potential (MIC 12.5 µg/mL) against B. megaterium than ampicillin (MIC 50 µg/mL). However, the other compounds did not exhibit any activity [57]. Compounds 70, 71, 138, 179, and 180 which were isolated from Pestalotiopsis sp. associated with Phytinula frasery were evaluated for their antimicrobial activities towards P. aeruginosa (ATCC 9027), S. aureus (ATCC 25923), E. coli (ATCC 25922), B. subtilis (ATCC 6633), and C. glabrata (ATCC 90030). It is noteworthy that only 138 had a promising antifungal capacity against C. glabrata (MIC$_{50}$ 3.49 µg/mL) in comparison to amphotericin B (MIC$_{50}$ 0.25 µg/mL). Whilst, the other metabolites had no activity (Conc. 50 µg/mL) [22]. The antimicrobial activity of 157–159 towards different aquatic and human pathogenic bacteria (E. coli, Aeromonas hydrophilia, P. aeruginosa, Micrococcus luteus, Vibrio alginolyticus, V. paraehemolyticus, and V. harveyi) and plant pathogenic fungi (Colletotrichum gloeosporioides and Phytophthora parasitica var. nicotianae) was evaluated. They had broad-spectrum antifungal and antibacterial capacities with MICs ranging from 4 to >64 µg/mL. Compound 157 possessed the highest activities against P. aeruginosa, E. coli, V. harveyi, C. gloeosporioides and V. parahaemolyticus (MICs 4 µg/mL), whereas 158 and 159 displayed moderate activities against these microorganisms [58]. Compound 165 (Conc. 500–7.8 µg/mL) which was biosynthesized by Exserohilum rostratum isolated from Bauhinia guianensis possessed a good activity towards B. subtilis (MIC 62.5 µg/mL and MIC 15.62 µg/mL), E. coli (MBC 250 µg/mL and MIC 15.62 µg/mL), P. aeruginosa (MIC 15.62 µg/mL), S. Typhimurium (MIC 31.25 µg/mL), and S. aureus (MIC 62.5 µg/mL) [59]. Microdochium bolleyi metabolites: 165, 167, 169, and 240 were estimated for their antibacterial, antifungal, and algicidal effects toward E. coli, B. megaterium, M. Violaceum, and C. fusca using agar diffusion assay. Compounds 165, 169, and 240 inhibited the four tested organisms. It is noteworthy that 167 showed an algicidal potential towards C. fusca (IZD 6 mm, actidione IZD 50 mm and nystatin IZD 20 mm) and an antifungal effect against M. violaceum (IZD 7 mm, tetracycline IZD 10 mm and actidione IZD 35 mm), but did not have an antibacterial effect [49]. Hussain et al. stated that 197 showed potential antifungal and antibacterial activities against M. violaceum (IZD 10 mm) and B. megaterium (IZD 5 mm), respectively [42]. Compounds 165, 167, 171, 175–177, and 201 were tested for their antimicrobial potentials towards S. aureus (CGMCC 1.2465), B. subtilis (ATCC 6633), S. pneumoniae (CGMCC 1.1692), F. oxysporum (CGMCC 3.2830), and E. coli (CGMCC 1.2340) [60]. Compounds 167 and 177 displayed antifungal potential towards F. oxysporum with MICs 20 µg/mL, compared to amphotericin B (MIC 0.63 µg/mL). Furthermore, 201 exhibited significant antibacterial effects against B. subtilis, S. pneumonia, and S. aureus with MICs 20, 10, and 5 µg/mL.
respectively in comparison to ampicillin (MICs 1.25, 10, and 0.16 µg/mL, respectively). Furthermore, it had a promising effect towards *E. coli* (MIC 20 µg/mL), compared to gentamicin (MIC 2.5 µg/mL) [60]. Arunpanichlert et al. reported that 213 had a mild antifungal effect against *Cryptococcus neoformans* and *C. albicans* with equal MICs of 200 µg/mL, while 212 was inactive (Conc. 200 mg/mL) [60]. Furthermore, 212 and 213 had a weak antibacterial effect against *B. subtilis* and *S. aureus* (Conc. 50 µg/mL) [61]. Chen et al. reported that the isocoumarins metabolites 54, 64–66, 84, 92–95, 150, 158, 159, 212, 213, 216, and 217 which were separated from *Talaromyces amestolkiae*, did not exhibit any antibacterial activity against *Staphylococcus epidermidis, S. aureus, Klebsiella pneumoniae, E. coli*, and *B. subtilis* [62]. Compounds 98, 99, 276–285, and 294 which were biosynthesized by *Aspergillus banksianus*, were tested for in vitro antimicrobial activities against *E. coli* (ATCC 25922), *B. subtilis* (ATCC 6633), *Saccharomyces cerevisiae* (ATCC 9763), and *C. albicans* (ATCC 10231). Compounds 283–285 displayed weak to moderate activities, whereas the other metabolites had no activity towards any of the tested strains [30]. Compound 232 showed a weak activity towards *B. subtilis* ATCC 6633 and *Trichophyton rubrum* ATCC 28,189 with MICs 19.7 and 32.0 µg/mL, respectively, compared to penicillin (MICs 0.9 µg/mL) and fluconazole (MIC 1.0 µg/mL) [63]. Moreover, compounds 172, 173, and 178 isolated from *Setosphaeria* sp. possessed no activity towards *S. aureus, Colletotrichum asiaticum, C. gloeosporioides, C. acutatum, Pyricularia oryzae*, and *F. oxysporum* using broth microdilution technique [64]. Compounds 72, 188, 189, 202–205, 207–211, 231, 233, 234, 286, and 287 were evaluated against *Agrobacterium tumefaciens, E. coli, Ralstonia solanacearum, S. aureus, Bacillus thuringiensis, Xanthomonas vesicatoria*, and *Pseudomonas lachrymans*. The metabolite 188 showed moderate inhibitory effect towards *A. tumefaciens, R. solanacearum, and S. aureus* with MICs 16 µM, while 189 and 234 had weak inhibition (MICs 32 µM) against *A. tumefaciens* and *R. solanacearum*, respectively [65]. The isocoumarins 88–90 and 272 exhibited no activities (MIC > 256 µg/mL) towards *P. aeruginosa, B. subtilis, S. aureus, E. coli*, and *C. albicans* [48]. The antifungal activity of 220 and 290 was assessed using the broth dilution method. Compound 290 showed significant antifungal capacity towards *Rhizoctonia solani* (MIC 6.25 µg/mL), compared to carbendazim (MIC 6.25 µg/mL) and moderate effect against *Colletotrichum musae* (MIC 25 µg/mL), whereas 220 exhibited weak activities toward these two fungi (MICs 150 µg/mL). However, none of these metabolites was active towards *Fusarium graminearum* and *Penicillium italicum* (MICs > 200 µg/mL) [66]. Compounds 188, 193–196, 232, and 299 biosynthesized by *Alternaria alternata* were tested against *B. subtilis* ATCC 6633, *S. aureus* ATCC 25923, *T. rubrum* ATCC 28,189, and *C. albicans* ATCC 24,433. Compound 194 ([(--)+] and [+]) displayed moderate effects against *S. aureus* (MICs 15.4 and 17.1 µg/mL, respectively), compared to penicillin MIC 1.2 µg/mL whereas 193, 195 ([(--)+] and [+]), and 196 had no prominent effect. These results demonstrated that the 2-OH acetylation could enhance the activity towards *S. aureus*, however, the enantiomer difference may have a negligible influence. Furthermore, (+)-194 and (+)-195 showed promising potential towards *C. albicans*, while (--)-194 and (--)195 had less activities, suggesting the difference in the antifungal potentials among the different enantiomers. Moreover, 188 possessed the highest activity towards *B. subtilis* (MIC 8.6 µg/mL). Whilst 232 had no activity [63] Bai et al. stated that compounds 186, 187, 244, 245, and 248 had no antibacterial potential towards *E. coli*, MRSA *S. aureus, S. aureus, B. cereus, Vibrio alginolyticus*, and *V. parahaemolyticus* using microplate assay [67]. Chen et al. reported that 296 had mild activity against *C. albicans* (MIC 32.0 µg/mL), compared to caspofungin (MIC 0.03 µg/mL) [29]. Compounds 1, 2, and 16 demonstrated a significant potential against *Trichophyton longifusus* and *Microsporum canis* (% inhibition 45, 70, and 55, respectively and 50, and 50, and 70, respectively), compared to miconazole, (% inhibition 70 and 98.4, respectively), whereas they were inactive towards *C. albicans, Fusarium solani, C. glabrata, and Aspergillus flavus* using agar tube dilution technique [68]. The antimicrobial potential of 237 and 238 separated *Trichoderma harzianum* was investigated towards *B. subtilis, E. coli*, *C. albicans, S. aureus*, and *P. aeruginosa* using well diffusion technique. They had a weak inhibitory effect against *E. coli* (MICs 32 µg/mL), compared to chloramphenicol (MIC 4 µg/mL), whereas they were inactive towards the other tested microorganisms [69]. Compounds 46 and 73 new isocoumarins reported from *Aspergillus* sp. SCSIO 41,501 derived from marine gorgonian *Melitodes squamata* were inactive against *E. coli* and *B. subtilis* using disc diffusion technique [70]. The new
isocoumarins metabolites, 13, 106, and 107 isolated Botryosphaeria ramosa were assessed for their antifungal potential towards F. oxysporum, P. italicum, and F. graminearum. Compounds 13 and 107 demonstrated a high inhibitory potential against F. graminearum and F. oxysporum (MICs 223 and 223 μM and 211.7 and 105.8 μM and respectively) in comparison to triadimefon (MICs 510.7 and 340.4 μM, respectively), whereas 106 had a significant activity against F. oxysporum (MIC 112.6 μM) and a weak effect towards F. graminearum (MIC 900 μM) [71]. Xu et al. reported that 145 displayed moderate activities against P. aeruginosa (MIC 50 μg/mL) and E. coli (MIC 12.5 μg/mL), compared to ciprofloxacin (0.078 and 0.625 μg/mL, respectively) [72]. The anti-bacterial activity of 100, 220, 239, 274, and 275 towards K. pneumonia, S. epidermidis, E. coli, S. aureus, and B. subtilis was assessed. Only 220 had activities against B. subtilis and S. aureus (MICs 25 μg/mL). While 100, 239, 274, and 275 (Conc. 25 μg/mL) did not exhibit any activity against the tested strains [73]. Compounds 162–164, novel dihydroisocoumarins isolated Geotrichum sp., associated with Crassocephalum crepidioides had been tested for the antifungal activity towards C. albicans using colorimetric technique [74]. Compounds 162 and 164 had a weak antifungal potential towards C. albicans (IC₅₀ 13 and 33 μg/mL, respectively), compared to amphotericin B (IC₅₀ 0.01 μg/mL). Whilst 163 had no activity [74]. Compounds 51, 146, and 147 possessed antibacterial potential towards B. subtilis (MICs 100, 50, and 25 μg/mL, respectively) and S. aureus (MICs 100, 25, and 25 μg/mL, respectively), compared to ciprofloxacin (MICs 0.25 and 0.13 μg/mL). However, they were inactive against E. coli, C. albicans, C. parapsilosis, and Cryptococcus neoformans [75]. The new isocoumarins 261–266 which were produced by Aspergillus sp. 085,242 separated from Acanthus ilicifolius roots exhibited no antibacterial capacity towards Staphylococcus epidermidis, S. aureus, E. coli, B. subtilis, and Klebsiella pneumoniae [76]. Compound 297 had a moderate antifungal capacity towards Botrytis cinerea, S. sclerotiorum, Phytophthora capsici, Fusarium graminearum, and F. moniliforme (inhibition rates 18.8, 39.0, 13.7, 24.0, and 31.6%, respectively) [77]. The isocoumarins 151–153, 214, 215, and 295 had no activity against B. cereus, E. coli, S. albus, S. aureus, B. subtilis, Kocuria rhizophila, Micrococcus tetragenus, Vibrio anguillarum, and V. paraehaemolyticus, whereas 153 possessed weak activity (MIC 12.5 μM) against S. aureus compared to ciprofloxacin (MIC 0.160 μM) [52]. Compounds 42, 304, and 306 reported from Selsamia galinsogisoli were assessed for the antimicrobial effect towards S. aureus, P. aeruginosa, B. subtilis, B. cereus, and K. pneumonia [78]. Compound 306 had selective activity against S. aureus (MIC 32 μg/mL), whereas 42 and 304 exhibited weak effects [78].

5.2. Cytotoxic Activity

The cytotoxic activities of isocoumarins have been assessed towards various cancer cell lines using various assays and the most active compounds have been listed in Table 3.

The cytotoxicity of 203, 219, and 221 reported from Ampelomyces sp. associated with Urosepermum picroides was assessed against L5178Y (mouse lymphoma) cells using MTT assay. Interestingly, 203 had a strong cytotoxic activity with EC₅₀ 7.3 μg/mL [39]. Compound 289 isolated from Trichoderma sp. was moderately active against HepG2 and MCF-7 cell lines (IC₅₀ 39.6 and 17.8 μg/mL, respectively) by MTT assay compared with epirubicin (IC₅₀ 5.3 and 5.2 μg/mL, respectively) [79]. The cytotoxicity of 165 and 168 towards CHAGO, BT474, HepG2, SW-620, and KATO-3 carcinomas was estimated using MTT colorimetric assay [46]. None of these metabolites was cytotoxic (Conc. 20 μg/mL) [46]. Compounds 160, 161, 165, and 166 were evaluated for the cytotoxic activity towards HuCCA-1, HepG2, MOLT-3, and A549 [80]. They were weakly cytotoxic (IC₅₀ 115.3–153.0 μM). Interestingly, 166 possessed selective cytotoxic activity (IC₅₀ 23.7 μM) toward HepG2 cell line, compared to etoposide (IC₅₀ 15.8 μM) [80]. Arunpanichlert et al. stated that 61, 212, and 213 which were separated from Pestalotiopsis sp., had no activity towards MCF-7, noncancerous Vero cell, and human oral cavity cancer [41]. Furthermore, the isocoumarin metabolites, 3, 88, 131, 165, and 293 biosynthesized by Botryosphaeria sp. KcF6 did not have cytotoxic capacity towards MCF-7, K562, U937, A549, HeLa, HL-60, DU145, MOLT-4, and BGC823 cancer cell lines [36]. Compounds 204, 222–230, 258, 267, and 268 did not exhibit cytotoxic potential towards MCF-7, HepG2, A549, HEK293T, and HeLa cell lines [31]. Ebada et al. reported that 259 and 260 (Conc. 10 μg/mL) had cytotoxic potential against L5178Y cell line with % growth inhibition 33
and 13, respectively using MTT assay [81]. The isocoumarins 98, 99, 276–285, and 294 biosynthesized by Aspergillus bambusianus were tested for in vitro activity against NS-1 cells. Compounds 283–285 displayed weak to moderate activity, whereas the other metabolites had no activity [30]. Compound 100 possessed no cytotoxicity against A2780 cell line [82]. Compounds 78 and 79, isocoumarin ribonic glycosides biosynthesized by Daldinia eschscholzii, had no obvious activity (IC₅₀ > 40 µg/mL) towards SMMC-7721, HL-60, A-549, SW-480, and MCF-7 using the MTT assay [54]. Compounds 183 and 184 were obtained from Talaromyces sp. that inhabited Cedrus deodara, showed cytotoxic potential towards HEP-1, A-549, THP-1, HCT, and PC-3 cell lines (% inhibition 23, 15, 54, 44, and 23%, respectively for 183 and 3, 35, 40, 35, and 34%, respectively for 184) [83]. Thomasin (141) showed no cytotoxicity (IC₅₀ > 50 µM) against Molm 1, HL-60, and PC-3 cell lines using MTT assay [84]. Compounds 154 and 155 had no cytotoxic potential against HeLa, MCF-7, and A549 cells (IC₅₀ > 50 µM) [56]. Compounds 157–159, dihydroisocoumarin derivatives reported from Penicillium simplicissimum were examined against Artemia salina (brine shrimp lethality). They showed brine shrimp lethality with LD₅₀ 7.7, 36.4, and 18.6 µg/mL, respectively, compared to colchicine (LD₅₀ 16.5 µg/mL) [58]. Alternariol (188) was reported to prevent cell proliferation by intervention with the cell cycle. The MTT assay results of the related derivatives from Alternaria sp. indicated that all alternariol derivatives demonstrated activity toward the L5178Y, except for 190 and 192. Compound 188 was the highly active metabolite (EC₅₀ 1.7 µg/mL), whereas 189 and 191 had activity with EC₅₀ 7.8 and 4.5 µg/mL, respectively. However, 193 was inactive [40]. Compounds 269–271 obtained from Alternaria tenus were tested for their in vitro cytotoxicity against A375-S2 and HeLa cells using MTT assay. Compounds 269 and 271 had a potent effect with IC₅₀ 0.1 and 0.02 mM and 0.3 and 0.05 mM, respectively. However, 270 displayed only weak activity (IC₅₀ 0.4 mM) to HeLa cells [85]. Fusariumin (298) a new isocoumarin derivative (Conc. 10 µg/mL) which was isolated from Fusarium sp. displayed a significant growth inhibitory potential against A. salina with mortality rate 78.2% [86]. Wang et al. reported that 188, 193–196, 232, and 299 were inactive (Conc. 50.0 µM) towards U2OS and HepG2 using the MTT method [63]. Furthermore, compounds 186, 187, 244, 245, and 248 had no activity towards HeLa, HepG2, and A549 cell lines [67]. Furthermore, 46 and 73 possessed no cytotoxicity towards MCF-7, HepG2, and HL60 cell lines using MTT assay [70]. Compound 296 possessed significant cytotoxicity towards AsPC-1 and MIA-PaCa-2 cell lines with IC₅₀ 5.53 and 1.63 µM, respectively, in comparison to gemcitabine (IC₅₀ 20.10 and 1.02 µM, respectively) [29]. Compounds 100, 220, 239, 274, and 275 were assessed for their cytotoxic effects towards HepG2, MDA-MB-435, HCT116, MCF10A, and H460 cell lines [73]. It is noteworthy that 274 had a selective cytotoxic potential towards HepG2, MDA-MB-435, MCF10A, and H460 (IC₅₀ 43.70, 5.08, 11.34, and 21.53 µM, respectively) comparable to epirubicin (IC₅₀ 0.32, 0.26, 0.13, 0.12 µM, respectively), whereas 275 showed a selective effect against MCF10A and MDA-MB-435 (IC₅₀ 21.40 and 4.98 µM, respectively). However, other metabolites (Conc. 50 µM) did not affect all tested cell lines [73]. The new isocoumarin metabolite, 20 isolated from Bruguiera sexangulara root-associated fungus Penicillium sp. 091,402 exhibited moderate cytotoxic potential towards K562 (IC₅₀ 18.9 µg/mL) [87]. Huang et al. reported that 142 inhibited HepG2 and Hep-2 cells growth (IC₅₀ 55 and 52 µg/mL, respectively) using MTT method [88]. The cytotoxic potential of 252 isolated Aspergillus versicolor was estimated towards A549, NB4, PC3, SHSY5Y, and MCF7. Interestingly, it had a higher activity towards MCF7 and A549 with IC₅₀ 8.0 and 5.8 µM, respectively [89]. The new isocoumarin, 108 isolated from Arthrinium sacchari displayed a weak cytotoxic effect towards HUVECs and HUAECs (IC₅₀ 70.8 and 277.1 µM, respectively), compared to Ki8751 (IC₅₀ 1.0–2.0 µM) using MTT assay [90]. Compound 35 did not have a cytotoxic effect against MRC-5 and AGS cell lines [91]. Moreover, 6 possessed no cytotoxic capacity against NCIH460, MCF-7, and A375-C5 cell lines using the protein binding dye SRB method [92]. The cytotoxic abilities against A549, NB4, MCF7, SHSY5Y, and PC3 tumor cell lines of 38, 52, 53, 127, 137, 251, and 301 were tested [93]. Compound 251 exhibited a high cytotoxic effect towards MCF7 and A549 cells (IC₅₀ 3.8 and 4.0 µM, respectively), in comparison to taxol (IC₅₀ 0.1 and 0.02 µM, respectively), while the other compounds had moderate cytotoxic capacities towards some of the tested cell lines with IC₅₀ less than 10 [93]. Compounds 23–29 were assessed for their cytotoxic
5.3. Antioxidant Activity

Choudhary et al. reported that 16 had a scavenging potential against DPPH (IC$_{50}$ 159 µM) in comparison to PG (IC$_{50}$ 30 µM) and BHA, also had a powerful XO inhibitory potential (IC$_{50}$ 243 µM), in comparison to BHA (IC$_{50}$ 591 µM) and PG (IC$_{50}$ 628 µM), while 2 showed a weak XO inhibitory potential (IC$_{50}$ 707 µM) [68]. Compounds 47, 50, and 134 exhibited no antioxidant capacities in the DPPH assay [95]. However, 90 showed a moderate DPPH scavenging activity with an IC$_{50}$ 58 µg/mL, compared to BHA (IC$_{50}$ 5.5 µg/mL) [96]. Compounds 161 and 166 scavenged DPPH with IC$_{50}$s 23.4 and 16.4 µM, respectively in comparison to ascorbic acid (IC$_{50}$ 21.2 µM) [80]. Furthermore, they prohibited the formation of superoxide anion radical with IC$_{50}$ values of 4.3 and 52.6 µM, respectively in the XO assay in relation to allopurinol (IC$_{50}$ 3.0 µM), whereas 165 showed no radical scavenging activities [80]. Moreover, they did not suppress the generation of superoxide anions induced by TPA to the oxidative stress by binding to ARE in the gene’s coding promoter for antioxidant enzymes and proteins [80]. Pang et al. reported that 172, 173, and 178 possessed no radical scavenging activity against DPPH [64]. The radical scavenging capacities of 261–266 were tested using DPPH. Only compounds 261 and 263 exhibited weak activity with EC$_{50}$s 125.0 and 130.0 µM, respectively compared to vitamin C (EC$_{50}$ 35.0 µM) [76]. The ability of compounds 72, 188, 189, 202–205, 207–211, 231, 233, 234, 286, and 287 to regulate Nrf2, that complies to the oxidative stress by binding to ARE in the gene’s coding promoter for antioxidant enzymes and protein for the synthesis of glutathione using ARE-driven luciferase reporters in HepG2C8 cells was evaluated. Compounds 209, 210, and 233 (a dose 10 µM) produced a significant induction of luciferase 1.93–2.95 folds more than DMSO (blank control), whereas TBHQ (positive control) invigorated the luciferase activation with 4 folds more than DMSO at a dose (50 µM) [65]. Compounds 80, 88, 118, 119, 303, and 307 isolated from Penicillium coeae were tested for their DPPH scavenging activities. Only 302 had a moderate effect (IC$_{50}$ 656 µM), compared to BHT (IC$_{50}$ 59 µM), whereas the rest compounds had no activities (IC$_{50}$ > 900 µM) [47].

5.4. α-Glucosidase, Acetylcholinesterase (AChE), and Protein Kinase Inhibitory Activities

α-Glucosidase is a carbohydrate, which is secreted from the epithelium of the small intestine [97,98]. It catalyzes the degradation of carbohydrates into α-glucose thus elevating the blood glucose level [99,100]. One of the therapeutic approaches for treating diabetes is to retard glucose absorption via inhibiting this enzyme. α-Glucosidase inhibitors slow down the digestion and absorption of carbohydrates by competitive blocking of the α-glucosidase activity [101]. Consequently, the postprandial blood glucose concentration is reduced [99–101]. Therefore, many efforts have been made to identify α-glucosidase inhibitors from natural sources.

Compounds 54, 64–66, 84, 92–95, 150, 158, 159, 212, 213, 216, and 217 were tested for the α-glucosidase inhibitory capacity [62]. Compounds 84, 95, 93, and 212 exhibited promising inhibitory activities (IC$_{50}$s 89.4, 17.2, 36.4, and 38.1 µM, respectively), better than acarbose (IC$_{50}$ 958.3 µM). The activity of 150, 213, 216, and 217 was five-fold more than that of acarbose. Compounds 65, 94, 66, 159, and 158 displayed moderate inhibitory activity with IC$_{50}$s 315.3, 302.6, 417.8, 266.3, and 431.4 µM, respectively. Moreover, 54, 65, and 66 had weak activity, whereas the other isocoumarins had activities similar to that of acarbose [62]. Compounds 114 and 115 biosynthesized by Aspergillus sp. were assessed for their in vitro α-glucosidase inhibitory capacities. Compound 114 exhibited more efficacy than that of acarbose (IC$_{50}$ 553.7 µM) with IC$_{50}$ 90.4 µM, whereas 115 was moderately active [38]. The new isocoumarins, 261–266 were assessed for the α-glucosidase inhibitory potential in comparison to
acarbose (IC$_{50}$ of 628.3 µM) [76]. Compounds 262, 265, and 266 showed moderate inhibitory effects with IC$_{50}$s 87.8, 52.3, and 95.6 µM, respectively [76]. Cui et al. reported that 203, 205, and 206 had a moderate inhibitory activity with IC$_{50}$s 343.7, 392.5, and 538.7 µM, respectively, compared to acarbose (IC$_{50}$ 815.3 µM) [33]. The α-glucosidase inhibitory capacities of 204, 222–230, 258, 267, and 268 which were biosynthesized by _Penicillium commune_ were evaluated. Compounds 224, 225, 227, and 228 possessed powerful activity (IC$_{50}$ 38.1–78.1 µM) than acarbose (IC$_{50}$ 478.4 µM). However, compounds 204, 223, and 224 were moderately active (IC$_{50}$s 102.4–158.4 µM) [31]. Compound 103 which was separated from _Xylariaeaeae_ sp. isolated from _Quercus gilva_ stem, possessed α-glucosidase inhibitory potential with IC$_{50}$ 41.75 µg/mL, compared to quercetin (IC$_{50}$ 4.80 µg/mL) [102]. The in vitro glucose consumption assay of 78 and 79 (Conc. 20 µg/mL) showed no activity with DMEM-induced 3T3 fibroblasts in the anti-diabetic model [54]. The α-glucosidase inhibitory activity of 76, 81, 82, 85–88, 93, and 95 which are reported from _Myrothecium_ sp. was investigated. Compounds 76, 81, 85, and 87 exhibited inhibitory potential towards the _Saccharomyces cerevisiae_ expressed human-sourced α-glucosidase recombinant with IC$_{50}$s 0.37, 0.32, 0.036, and 0.026 mM, respectively compared to acarbose (IC$_{50}$ 0.47 mM) [103]. Compounds 165, 167, 174, and 218 biosynthesized by _Leptosphaena maculans_ did not show any inhibitory effects against α-glucosidase [104].

Acetylcholinesterase (AChE), an enzyme that catalyzes acetylcholine (ACh) hydrolysis leading to a decrease in the levels of ACh in the brain [105]. Thus, appears to be a critical element in the development of neurodegenerative diseases such as Alzheimer’s disease (AD) and dementia. The most suitable therapeutic approach for treating AD and other forms of dementia is to restore ACh levels by inhibiting AChE [106]. Compounds 3, 6, and 8 were evaluated for their AChE inhibitory activities. Compound 6 had a moderate AChE inhibitory potential with a limit of detection 30.0 µg, whereas 3 and 8 were inactive (limit of detection over 100 µg) [18]. Compounds 34, 36, and 37 showed weak inhibition of AChE with a limit of detection 10 µg in a TLC-based AChE inhibition assay [17]. Only 34 displayed moderate AChE inhibitory activity (limit of detection 3.0 µg) compared to galantamine (MICs 1.0 µg) [17].

Protein kinases are enzymes that catalyze the transfer of a phosphate group from a high energy molecule such as adenine triphosphate (ATP) to a specific amino acid. They play important roles in regulating many cellular functions, including survival, proliferation, motility, apoptosis, as well as DNA damage repair and metabolism [107]. Some of them are commonly activated in cancer cells and known to play roles in tumorigenesis [108]. Protein kinases inhibitors are anticipated to be a source of potential therapeutic targets for treating various human disorders such as neoplastic and neuroinflammatory diseases [107,108]. The isolated alternariol derivatives from _Alternaria_ sp. were assessed for their inhibitory activities against 24 protein kinases. Interestingly, alternariol (188) and its derivatives 189–191 prohibited protein kinases: Aurora A, ARK5, Aurora B, IGF1-R, b-RAF, VEGF-R2, FLT3, VEGF-R3, SAK, and PDGF-Rbeta with IC$_{50}$ below 1 × 10$^{-6}$ g/mL. Moreover, 193 exhibited activity with an IC$_{50}$ 1 × 10$^{-5}$ g/mL or less towards the various tested kinases [40].

### 5.5. Anti-Inflammatory Activity

Compounds 3, 88, 131, 165, and 293 were assessed for their COX-2 inhibitory activities. Only 293 exhibited significant inhibitory activity with an IC$_{50}$ 6.51 µM [36]. The anti-inflammatory activities of 203, 208, 220, 221, 251, 288, 289, 291, and 292 were assessed against NO production in the LPS-stimulated mouse macrophage RAW 264.7 [37]. Compound 292 had a potent inhibitory capacity (IC$_{50}$ 15.8 µM), whereas 220, 221, and 291 were weakly active compared to indomethacin (IC$_{50}$ 37.5 µM), while the other compounds had no inhibitory potential (IC$_{50}$ > 100 µM) [37]. Annulohypoxylomarin A (7) derived from the endophytic fungus _A. truncatum_ did not affect (IC$_{50}$ > 100 µM) the production of TNF-α, IL-12 p40, and IL-6 in LPS-stimulated bone marrow-derived dendritic cells [45]. Compounds 166, 187, 244, 245, and 248 did not affect the NO production in LPS-induced RAW 246.7 mouse macrophages [67]. Compounds 19 and 36 biosynthesized by _Xylaria cubensis_ associated with _Litsa aokoensis_ leaves were assessed for their capacities to prohibit IL-6 and NO production in LPS-activated RAW 264.7 cells.
It is noteworthy that 36 had IL-6 inhibitory potential with IC₅₀ 9.4 µM [109]. Compounds 23 and 27 had moderate inhibitory effects on the production NO in LPS-induced RAW 264.7 cells (IC₅₀ 26.3 and 38.7 µM, respectively) with no observed toxicities at 50 µM [51].

5.6. Anti-Mycobacterial, Antiplasmodial, Antiviral, and Insecticidal Activities

Compounds 204, 222–230, 258, 267, and 268 (Conc. 50 µM) were tested for their Mycobacterium protein tyrosine phosphatase B (MptpB) inhibitory activity [31]. Compound 225 had MptpB inhibitory effect (IC₅₀ 20.7 µM), compared to oleanolic acid (IC₅₀ 22.1 µM), however, the other compounds possessed weak or no inhibitory effects at the same concentration [31]. Arunpanichlert et al. reported that compounds 61, 212, and 213 showed no activity against Mycobacterium tuberculosis [41]. Compounds 162 and 163 showed weak antituberculosis potential against M. tuberculosis H27Ra (IC₅₀ 25 and 50 µg/mL, respectively), in comparison to kanamycin sulfate and isoniazid (IC₅₀ 0.050 and 2.5 µg/mL, respectively) using MABA, whereas 164 had no activity [74]. The antiplasmodial activity against the multidrug-resistant K1 strain of Plasmodium falciparum of 165 and 168 was estimated using microculture radioisotope technique [46]. Compound 165 showed antiplasmodial activity (IC₅₀ 0.68 µM). However, its 11-hydroxy analog (168) had a 10-fold lower activity, suggesting that the existence of the OH group in the n-propyl chain decreases the activity. Compounds 61, 212, and 213 had no antimalarial activity towards P. falciparum [41]. Furthermore, 6 and 35 had no antimalarial potential against K1 strain of P. falciparum [110,111]. Compounds 98, 99, 276–285, and 294 were tested for in vitro activity against Tritrichomonas fetus (KV-1). The results revealed that 283–285 displayed weak to moderate activity, whereas the other metabolites had no activity [30]. Compounds 162 and 163 showed significant antimalarial potential with IC₅₀ 4.7 and 2.6 µg/mL, respectively, compared to chloroquine diphosphate (IC₅₀ 0.16 µg/mL) towards P. falciparum (K1, multi-drug resistant strain) using microculture radioisotope technique [74]. However, 163 was inactive [74]. Compound 11 separated from the endophytic fungus Phoma sp. exhibited antiviral activity against influenza A virus (A/Puerto Rico/8/34, H1N1) with IC₅₀ 20.98 µg/mL, compared to arbidol (IC₅₀ 0.15 µg/mL) [26]. The anti-tobacco mosaic virus (anti-TMV) activities 39, 67–69, 96, 97, and 137 (Conc. 20 µM) produced by P. oxalicum, isolated from Nicotiana sanderae leaves was screened using the half-leaf method [44]. The results showed that 67 had the highest activity (% inhibition 25.4). While other compounds possessed weak activity with an inhibition rate ranging from 11.3 to 18.9% [44]. Duan et al. mentioned that 40 and 41 (Conc. 20 µM) had anti-TMV capacities (inhibition rates 18.6 and 21.8%, respectively) using the half-leaf technique [112]. The anti-TMV activities of 38, 52, 53, 127, 137, 251, and 301 were evaluated using the half-leaf method at a concentration 20 µM. Interestingly, 251 showed a high anti-TMV potential (inhibition rate 28.6%), compared to ningnanmycin (inhibition rate 31.5%), whereas the other metabolites had a moderate activity (inhibition rates 15.6–22.0%) [93]. Oryzaeins A (111) and B (112), new isocoumarin derivatives isolated from Aspergillus oryzae were tested for their anti-TMV utilizing the half-leaf assay at Conc. 20 µM. The results revealed that 111 and 112 had moderate anti-TMV potential (inhibition rates 28.4 and 30.6%, respectively) [94]. Antifeedant activities of 134 and 135 were evaluated against larvae of Spodoptera littoralis using glass-fiber discs. Compound 135 possessed activity at 100 ppm with feeding index 42.1, whereas 134 did not affect the feeding (feeding index 30.1) [55]. The new isocoumarins, 186, 187, 244, 245, and 248 displayed a growth inhibitory activity toward Helicoverpa armigera Hubner (IC₅₀ s 200, 200, 200, 100, and 100, µg/mL, respectively), compared to azadirachtin (IC₅₀ 25 µg/mL) [67].

5.7. Other Biological Activities

The antischistosomal activity of 6 and 35 was estimated against Schistosoma mansoni adult worms. It is noteworthy that 6 and 35 (Conc. 50 and 200 µg/mL, respectively) caused 100% death of the parasites, compared to praziquantel (Conc. 12.5 µg/mL) [113]. Compounds 6 and 131 produced by Neofusicoccum parvum, showed phytotoxic activity on tomato plants with symptoms ranging from slight to drastic wilting of leaves [114]. Nakashima et al. reported that 87, 109, 148, and 149 isolated from Houttuynia cordata leaves associated fungus Tubakia sp. ECN-111 had no agonistic activity for a liver
X-receptor and peroxisome proliferator-activated receptor-C in a luciferase reporter gene assay [115]. Compounds 160, 161, 165, and 166 did not prohibit aromatase (CYP19) enzyme (IC₅₀ 15.3–16.9 µM) [80]. Compound 300 produced by Penicillium sp. possessed moderate inhibitory activity on the Arabidopsis thaliana seeds germination [116].

6. Conclusions

Endophytic fungi have been emerged as a new area for the discovery of new pharmaceutical candidates and continue to be a prosperous pool of bioactive and structurally unique metabolites. The isocoumarins and 3,4-dihydroisocoumarins ring system is present in nature with an enormous spectrum of bioactivities, extending from antibacterial to anticancer. According to this review, the distinctive pharmacological significance of these metabolites initiates much research to be done and still going on towards the advancement and synthesis of their derivatives. The inactivity reported for some derivatives in former studies could be due to prejudice in the evaluation experiments. Further assessments of these metabolites with wider spectrum screening systems are endorsed, which may lead to the invention of their interesting activities.
Table 1. List of fungal isocoumarins (Fungal source, host, and place).

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Kigelin (1)   | Aspergillus terrus BDKU 1164 | Marine alga | Mubarak village beach, Karachi, Pakistan | [68] |
| (−)-(3R)-6,7-Dimethoxymellein (2) | Aspergillus terrus BDKU 1164 | Marine alga | Mubarak village beach, Karachi, Pakistan | [68] |
| 8-Methoxymellein (3) | Penicillium sp.1 and sp.2 | Alibertia macrophylla (Leaves, Rubiaceae) | Mogi-Guaçu, São Paulo, Brazil | [18] |
| 8-Deoxy-6-hydroxy-cis-4-acetoxyoxymellein (5) | Ascomycete 6650 | Meliotus dentatus (Leaves, Fabaceae) | Baltic Sea, Ahrenshoop, Germany | [50] |
| Cis-4-Acetoxyoxymellein (4) | Ascomycete 6650 | Meliotus dentatus (Leaves, Fabaceae) | Baltic Sea, Ahrenshoop, Germany | [50] |
| 8-Deoxy-6-hydroxy-cis-4-acetoxyoxymellein (5) | Ascomycete 6650 | Meliotus dentatus (Leaves, Fabaceae) | Baltic Sea, Ahrenshoop, Germany | [50] |
| (3R,4R)-(−)-4-Hydroxymellein (3R,4R)-Cis-4-Hydroxymellein (6) | Aspergillus terrus BDKU 1164 | Marine alga | Mubarak village beach, Karachi, Pakistan | [68] |
| Xylaria sp. PBR-30 | Sandoricum koetjape (Leaves, Meliaceae) | Prachinburi Province, Thailand | [111] |
| Ascocytta sp. | Meliotus dentatus (Whole plant, Fabaceae) | Shores of the Baltic Sea, near Ahrenshoop, Germany | [117] |
| Nigrospora sp. PSU-N24 | Garcinia nigrolineata (Branches, Clusiaceae) | Ton Nga Chang wildlife sanctuary, Songkhla province, Southern Thailand | [110] |
| Neofusicoccum parvum | Vitis vinifera L. (Cankered branches, Vitaceae) | Catalonia, NE Spain | [114] |
| Emericellopsis minima | Hyrtios erecta (Marine sponge) | Similan islands, Phag Nga Province, Thailand | [92] |
| Apiospora montagnei Sacc. | Ssmallanthus sonchifolius (Roots, Asteraceae) | Ribeirão Preto city, S. P. State, Brazil | [113] |
| Lachnum palmae | Przewalskia tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Annulohypoxylomarin (7) | *Annulohypoxylon truncatum* | *Zizania caduciflora* (Leaves, Poaceae) | Suncheon, South Korea | [45] |
| 5-Hydroxymellein (8) | *Penicillium* sp.1 and sp.2 | *Alibertia macrophylla* (Leaves, Rubiaceae) | Mogi-Guaçu, São Paulo, Brazil | [18] |
| | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| (3R)-6-Methoxy-7-chloromellein (9) | *Phoma* sp. 135 | *Ectyplasia perox* | Lauro Club Reef, Dominica | [32] |
| (3R,4R)-Cis-4-Hydroxy-5-methylmellein (10) | Unidentified *Ascomycete* 6650 | *Melilotus dentatus* (Leaves, Fabaceae) | Baltic Sea, Ahrenshoop, Germany | [43] |
| (−)-6-Methoxymellein (11) | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| | *Phoma* sp. YE3135 | *Aconitum vilmorinianum* (Roots, Ranunculaceae) | Yunnan University, China | [26] |
| (3R,4S)-4-Hydroxy-6-methoxy-7-chloromellein (12) | *Phoma* sp. 135 | *Ectyplasia perox* | Lauro Club Reef, Dominica | [32] |
| Botryospyrone C (13) | *Botryosphaeria ramosa* L29 | *Myoporum bontioides* (Leaves, Scrophulariaceae) | Leizhou Peninsula, China | [71] |
| Botryospyrone D (14) | *Botryosphaeria ramosa* L29 | *Myoporum bontioides* (Leaves, Scrophulariaceae) | Leizhou Peninsula, China | [71] |
| 3R-(+)-5-O-[6′-O-Acetyl]-α-D-glucopyranosyl-5-hydroxymellein (15) | *Xylaria* sp. cfcc 87468 | *Pinus tabuliformis* (Leaves, Pinaceae) | China Forestry Culture Collection Center, Beijing, China | [118] |
| 6-(4′-Hydroxy-2′-methyl phenoxy)-(−)-(3R)-mellein (16) | *Aspergillus terras* BDKU 1164 | Marine alga | Mubarak village beach, Karachi, Pakistan | [68] |
| (3R)-7-Hydroxy-5-methylmellein (17) | *Phomopsis* sp. 7233 | *Laurus azorica* (Leaves, Lauraceae) | Gomera, Spain | [42] |
| | *Biscogniauxia capnodes* | *Averrhoa carambola* L. (Fruits, Oxalidaceae) | Home garden in Kandy, Central Province, Sri Lanka | [96] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Akolitserin (18) (+)-(3R,4S)-5-Carbomethoxy-3-hydroxymellicin Methyl (3R,4S)-3,4-Dihydro-4,8-dihydroxy-3-methyl-1-oxo-1H-isochromene-5-carboxylate | Xylaria cubensis BCRC 09F 0035 | Litsea akoensis Hayata (Leaves, Lauraceae) | Kaohsiung, Taiwan | [109] |
| (−)-(R)-5-(Methoxycarbonyl)mellicin (19) | Xylaria cubensis BCRC 09F 0035 | Litsea akoensis Hayata (Leaves, Lauraceae) | Kaohsiung, Taiwan | [109] |
| (3R,4S)-6,8-Dihydroxy-3,4,7-trimethylisocoumarin (20) | Penicillium sp. 091402 | Bruguiera sexangula (Roots, Rhizophoraceae) | Qinglan Port, Hainan, China | [87] |
| (3R,4S)-6,8-Dihydroxy-3,4,5,7-tetramethylisochroman (21) | Penicillium sp. 091402 | Bruguiera sexangula (Roots, Rhizophoraceae) | Qinglan Port, Hainan, China | [87] |
| Palmaerone A (23) (R)-5-Bromo-6-hydroxy-8-methoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone B (24) (R)-7-Bromo-6-hydroxy-8-methoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone C (25) (R)-7-Bromo-6,8-dimethoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone D (26) (R)-7-Bromo-6-hydroxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone E (27) (R)-5-Bromo-6,7-dihydroxy-8-methoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone F (28) (R)-5-Chloro-6-hydroxy-8-methoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerone G (29) (R)-7-Chloro-6-hydroxy-8-methoxy-mellicin | Lachnum palmae | Przewalska tangutica Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| (R)-5-Chloro-6-hydroxymellein (30) | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerin A (31) | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerin B (32) | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| Palmaerin D (33) | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| (3R,4R)-3,4-Dihydro-4,6-dihydroxy-3-methyl-1-oxo-1H-isocoumarin (34) | *Xylaria sp. PA-01* | *Piper aduncum* (Leaves, Piperaceae) | Mogi-Guaçu, São Paulo, Brazil | [17] |
| (3R)-Mellein (35) | Centraalbureau voor Schimmel 120379 | *Picea glauca* (Leaves, Pinaceae) | Sussex, New Brunswick, Canada | [119] |
| | *Nigrospora* sp. PSU-N24 | *Garcinia nigrolineata* (Branches, Clusiaceae) | Ton Nga Chang wildlife sanctuary, Songkhla province, Southern Thailand | [119] |
| | *Nigrospora* sp. LLGLM003 | *Moringa oleifera* (Roots, Moringaceae) | Xiamen municipality, Fujian Province, China | [53] |
| | *Apiospora montagnei* Sacc. | *Smallanthus sonchifolius* (Roots, Asteraceae) | Ribeirão Preto city, S. P. State, Brazil | [113] |
| | *Lasiodiplodia* sp. ME4-2 | *Viscum coloratum* (Flowers, Santalaceae) | Hangzhou City, Zhejiang Province, China | [120] |
| | *Sarcosomataceae* sp. NO.49-14-2-1 | *Everniastrum nepalense* (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| | *Penicillium janczewskii* | *Prumnopitys andina* (Phloem, Podocarpaceae) | Western Andean slopes near Las Trancas, Chillan | [91] |
| | *Lachnum palmae* | *Przewalskia tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
Table 1. Cont.

| Compound Name                                      | Fungus                        | Host (Part, Family)                                                                  | Source, Place                                           | References |
|----------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------|------------|
| (R)-7-Hydroxymellein (36)                         | Penicillium sp. 05070032-C    | *Alibertia macrophylla* (Leaves, Rubiaceae)                                           | Mogi-Guaçu, São Paulo, Brazil                           | [17]       |
|                                                    | *Xylaria cubensis* BCRC 09F 0035 | *Litsea akoensis* Hayata (Leaves, Lauraceae)                                           | Kaohsiung, Taiwan                                      | [109]      |
| (3R,4R)-4,7-Dihydroxymellein (37)                 | Penicillium sp. 05070032-C    | *Alibertia macrophylla* (Leaves, Rubiaceae)                                           | Mogi-Guaçu, São Paulo, Brazil                           | [17]       |
| Angelicoin A (38)                                 | *Aspergillus versicolor* 0456  | *Nicotiana sanderae* (Leaves, Solanaceae)                                             | Shilin, Yunnan Province, China                         | [122]      |
|                                                    | *Aspergillus versicolor*      | *Paris marmorata* Stearn (Rhizomes, Melanthiaceae)                                     | Dali, Yunnan, China                                    | [93]       |
| Periplanetin A (39)                               | *Penicillium oxalicum* 0403   | *Nicotiana sanderae* (Leaves, Solanaceae)                                             | Shilin, Yunnan Province, China                         | [44]       |
| (3R)-Methyl-8-hydroxy-6-(hydroxymethyl)-7-methoxydihydroisocoumarin (40) | *Aspergillus versicolor*      | *Nicotiana tabacum* (Rhizomes, Solanaceae)                                             | Chuxiong, Yunnan, China                                | [112]      |
| (3R)-Methyl-7,8-dimethoxy-6-(hydroxymethyl)dihydro-isocoumarin (41) | *Aspergillus versicolor*      | *Nicotiana tabacum* (Rhizomes, Solanaceae)                                             | Chuxiong, Yunnan, China                                | [112]      |
| (R)-6-Hydroxymellein (42)                         | *Aspergillus versicolor*      | *Nicotiana tabacum* (Rhizomes, Solanaceae)                                             | Chuxiong, Yunnan, China                                | [112]      |
|                                                    | *Lachnum palmae*              | *Przewalska tangutica* Maxim. (Leaves, Solanaceae)                                     | Linzhou Country of the Tibet Autonomous Region,        | [51]       |
|                                                    | *Selinsia galinsogisoli* sp. nov. SYPF 7336 | *Galinsoga parviflora* (Whole plant, Asteraceae)                                       | Huludao, China                                         | [78]       |
| 6,8-Dimethoxy-3-methyl-3,4-dihydro-1H-isochromen-1-one (43) | *Aspergillus versicolor*      | *Nicotiana tabacum* (Rhizomes, Solanaceae)                                             | Chuxiong, Yunnan, China                                | [112]      |
| Periplanetin B (44)                               | *Aspergillus versicolor*      | *Nicotiana tabacum* (Rhizomes, Solanaceae)                                             | Chuxiong, Yunnan, China                                | [112]      |
| Arundinone A (45)                                 | *Microsphaeropsis arundinis*  | *Ulmus macrocarpa* (Stems, Ulmaceae)                                                   | Dongling Mountain, Beijing, China                      | [123]      |
| Aspergillspin F (46)                              | *Aspergillus* sp. SCSIO 41501 | *Melitodes squamata* (Gorgonian, Plexauridae)                                           | South China Sea, Sanya Hainan Province, China          | [70]       |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|--------------|------------|
| (3R)-5-Carbomethoxymellein (47) | Centra alburne voor Schimmel cultures 120379 | *Picea glauca* (Leaves, Pinaceae) | Sussex, New Brunswick, Canada | [119] |
| 5-Carbomethoxy-3,4-dihydro-8-hydroxy-(3R)-methylisocoumarin | | | | |
| (3R)-5-Formylmellein (48) | Centraalbureau voor Schimmel 120379 | *Picea glauca* (Leaves, Pinaceae) | Sussex, New Brunswick, Canada | [119] |
| 3,4-Dihydro-5-formyl-8-hydroxy-(3R)-methylisocoumarin | | | | |
| Xylarellein (49) | *Xylaria* sp. PSU-G12 | *Garcinia hombroniana* (Branch, Clusiaceae) | Songkhla province, Thailand | [95] |
| (3R)-5-Carboxylmellein (50) | *Xylaria* sp. PSU-G12 | *Garcinia hombroniana* (Branches, Clusiaceae) | Songkhla province, Thailand | [95] |
| Gamahorin (51) | *Pestalotiopsis heterocorns* | *Phakellia fusca* (Sponge, Axinellidae) | Xisha Islands, China | [75] |
| Versicoumarin B (52) | *Aspergillus versicolor* | *Paris marmorata* Stearn (Rhizomes, Melanthiaceae) | Dali, Yunnan, China | [93] |
| Versicoumarin C (53) | *Aspergillus versicolor* | *Paris marmorata* Stearn (Rhizomes, Melanthiaceae) | Dali, Yunnan, China | [93] |
| S-(-)-6-Hydroxy-8-methoxy-4-(1'-hydroxyethyl)-isocoumarin (54) | *Talaromyces Amestolkiae* YX1 | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| Acetic acid 6,8-dihydroxy-3,5-dimethyl-1-oxo-1H-isochroman-4-ylmethyl ester (55) | *Scytalidium* sp. 5681 | *Salix* sp. (Leaves, Salicaceae) | Harz Mountains, Lower Saxony, Germany | [27] |
| 6,8-Dihydroxy-4-hydroxymethyl-3,5-dimethyl-isochroman-1-one (56) | *Scytalidium* sp. 5681 | *Salix* sp. (Leaves, Salicaceae) | Harz Mountains, Lower Saxony, Germany | [27] |
| Decarboxycitrinone (57) | *Scytalidium* sp. 5681 | *Salix* sp. (Leaves, Salicaceae) | Harz Mountains, Lower Saxony, Germany | [27] |
| 4-Acetyl-6,8-dihydroxy-5-methyl-2-benzopyran-1-one (58) | *Scytalidium* sp. 5681 | *Salix* sp. (Leaves, Salicaceae) | Harz Mountains, Lower Saxony, Germany | [27] |
| 6,8-Diacetoxy-3,5-dimethylisocoumarin (59) | *Myceila sterile* 4567 | *Cirsium arvense* (Asteraceae) | Lower Saxony, Germany | [20] |
| Penicilisorin (60) | *Penicillium sclerotiorum* PSU13 | *Garcinia atroviridis* (Leaves, Clusiaceae) | Yala Province, Thailand | [124] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Pestalotiorin (61) | *Pestalotiopsis* sp. PSU-ES194 | *Enhalus acoroides* (Leaves, Hydrocharitaceae) | Songkla Province, Thailand | [41] |
| Tabaisocoumarin A (62) | *Aspergillus versicolor* 0456 | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China | [122] |
| | *Aspergillus oryzae* | *Paris polyphylla var. yunnanensis* (Franch.) Hand.-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China | [94] |
| 3-Acetoxyl-8-hydroxyl-isocoumarin (63) | *Sarcosomataceae* sp. NO.49-14-2-1 | *Everniastrum nepalense* (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| 6-Hydroxy-4-(1-hydroxyethyl)-8-methoxy-1H-isochromen-1-one (64) | *Talaromyces amestolkiae* | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| S-(-)-5,6,8-Trihydroxy-4-(1′-hydroxyethyl)isocoumarin (65) | *Penicillium* sp. MWZ14-4 | Unidentified sponge GX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China | [52] |
| | *Talaromyces amestolkiae* | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| Sescandelin (66) | *Penicillium* sp. MWZ14-4 | Unidentified sponge GX-WZ-2008001 (Inner fresh tissue) | Weizhou, South China Sea, China | [52] |
| | *Talaromyces amestolkiae* | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| Terrecoumarin A (67) | *Penicillium oxalicum* 0403 | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China | [44] |
| Terrecoumarin B (68) | *Penicillium oxalicum* 0403 | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China | [44] |
| Terrecoumarin C (69) | *Penicillium oxalicum* 0403 | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China | [44] |
| Pestapyrone D (70) | *Pestalotiopsis* sp. | *Photinia frasery* (Leaves, Amygdaloideae) | Nanjing, Jiangsu, China | [22] |
| Pestapyrone E (71) | *Pestalotiopsis* sp. | *Photinia frasery* (Leaves, Amygdaloideae) | Nanjing, Jiangsu, China | [22] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| LL-Z 1640-7 (72) | Peyronellaea glomerata XSB-01-15 | Amphinemdon sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| Aspergillspin G (73) | Aspergillus sp. SCSIO 41501 | Melitodes squamata (Gorgonian, Plexauridae) | South China Sea, Sanya Hainan Province, China | [70] |
| Acremonone E (74) | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae) | Satun Province, Thailand | [125] |
| Acremonone F (75) | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae) | Satun Province, Thailand | [125] |
| Acremonone G (76) | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae) | Satun Province, Thailand | [125] |
| Acremonone H (77) | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae) | Satun Province, Thailand | [125] |
| Daldiniside B (78) | Daldinia eschscholzii | Scaevola sericea Vahl (Branches, Goodeniaceae) | Hainan province, China | [54] |
| Daldiniside C (79) | Daldinia eschscholzii | Scaevola sericea Vahl (Branches, Goodeniaceae) | Hainan province, China | [54] |
| de-O-Methyldiaporthin (80) | Daldinia eschscholzii | Scaevola sericea Vahl (Branches, Goodeniaceae) | Hainan province, China | [54] |
| Myrothelactone A (81) | Myrothecium sp. OUCMDZ-2784 | Apocynum venetum (Leaves, Apocynaceae) | Dongying, China | [103] |
| Myrothelactone B (82) | Myrothecium sp. OUCMDZ-2784 | Apocynum venetum (Leaves, Apocynaceae) | Dongying, China | [103] |
| 3-Methyl-8-hydroxyisocoumarin (83) | Sarcosomataceae sp. NO.49-14-2-1 | Everniastrum nepalense (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| 6,8-Dihydroxy-5-methoxy-3-methyl-1H-isochromen-1-one (84) | Talaromyces amestolkiae | Kandelia obovata (Leave, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Myrothelactone C (85) | *Myrothecium* sp. OUCMDZ-2784 | *Apocynum venetum* (Leaves, Apocynaceae) | Dongying, China | [103] |
| Myrothelactone D (86) | *Myrothecium* sp. OUCMDZ-2784 | *Apocynum venetum* (Leaves, Apocynaceae) | Dongying, China | [103] |
| Tubakialactone B (87) | *Tubakia* sp. ECN-111 | *Houttuynia cordata* Thumb (Leaves, Saururaceae) | Chikusa-ku Nagoya city, Japan | [115] |
| *Tubakia* sp. ECN-111 | *Myrothecium* sp. OUCMDZ-2784 | *Apocynum venetum* (Leaves, Apocynaceae) | Dongying, China | [103] |
| Saccharonol A (88) | *Aspergillus* similanensis sp. nov. KUFA 0013 | *Rhabderea* sp. (Sponge, Rhabderemiidae) | Phang Nga Province, Thailand | [48] |
| *Penicillium* co*ff*eae MA-314 | *Botryosphaeria* sp. KcF6 | *Kandelia candel* (Fruits, Rhizophoraceae) | Daya Bay, Shenzhen, China | [36] |
| Saccharonol A (88) | *Aspergillus* versicolor KJ801852 | *Paris polyphylla* var. *yunnanensis* (Rhizomes, Melanthiaceae) | Dali, Yunnan, China | [126] |
| *Penicillium* co*ff*eae MA-314 | *Myrothecium* sp. OUCMDZ-2784 | *Apocynum venetum* (Leaves, Apocynaceae) | Dongying, China | [103] |
| Reticulol (90) | *Aspergillus* similanensis sp. nov. KUFA 0013 | *Rhabderea* sp. (Sponge, Rhabderemiidae) | Phang Nga Province, Thailand | [48] |
| 6-Hydroxy-4-hydroxymethyl-8-methoxy-3-methylisocoumarin (91) | *Endophytic fungus* (No. GX4-1B) | *Bruguiera gymnolhiza* (L.) Savigny (Branch, Rhizophoraceae) | South China Sea in Guangxi province, China | [127] |
| Retinol (92) | *Botryosphaeria* sp. HQD-6 | *Rhizophora mucronata* (Leaves, Rhizophoraceae) | Hainan Island, China | [126] |
| 6-Hydroxy-8-methoxy-3,4-dimethylisocoumarin (92) | *Biscogniauxia capnodes* | *Averrhoa carambola* L. (Fruits, Oxalidaceae) | Kandy, Central Province, Sri Lanka | [96] |
| 6-Hydroxy-8-methoxy-3,4-dimethylisocoumarin (92) | *Biscogniauxia capnodes* | *Averrhoa carambola* L. (Fruits, Oxalidaceae) | Kandy, Central Province, Sri Lanka | [96] |
| 6-Hydroxy-8-methoxy-3,4-dimethylisocoumarin (92) | *Biscogniauxia capnodes* | *Averrhoa carambola* L. (Fruits, Oxalidaceae) | Kandy, Central Province, Sri Lanka | [96] |
| Compound Name                                           | Fungus                                    | Host (Part, Family)                  | Source, Place                                           | References |
|---------------------------------------------------------|-------------------------------------------|--------------------------------------|---------------------------------------------------------|------------|
| 3,4-Dimethyl-6,8-dihydroxyisocoumarin (93)              | *Talaromyces amestolkiae*                 | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China                     | [62]       |
| Nectaria pseudotrichia 120-1NP                          |                                           | *Gliricidia sepium* (Stems, Fabaceae)  | Wanagama forest of Universitas, Yogyakarta, Indonesia    | [128]      |
| 6-Hydroxy-4-hydroxymethyl-8-methoxy-3-methyl-isocoumarin (94) | *Talaromyces amestolkiae*                 | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China                     | [62]       |
| Sescandelin B (95)                                      | *Talaromyces amestolkiae*                 | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China                     | [62]       |
|                                                         | *Myrothecium* sp. OUCMDZ-2784             | *Apocynum venetum* (Leaves, Apocynaceae) | Dongying, China                                         | [103]      |
| 6-Hydroxy-3-hydroxymethyl-8-methoxyisocoumarin (96)     | *Penicillium oxalicum* 0403               | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China                           | [44]       |
| 4,6-Dihydroxy-3,9-dehydromellein (97)                   | *Penicillium oxalicum* 0403               | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China                           | [44]       |
| Banksiamarin A (98)                                     | *Aspergillus versicolor* KJ801852          | *Paris polyphylla* var. yunnanensis (Rhizomes, Melanthiaceae) | Dali, Yunnan, China                                     | [126]      |
| Banksiamarin B (99)                                     | *Aspergillus banksianus* sp. nov           | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                    | [30]       |
| 6,8-Dihydroxyisocoumarin-3-carboxylic acid (100)        | *Bionectria* sp.                          | *Raphia taedigera* (Seeds, Arecaceae)  | Haut Plateaux region, Cameroon                           | [82]       |
| Nectria pseudotrichia 120-1NP                           |                                           | *Gliricidia sepium* (Stems, Fabaceae)  | Wanagama forest of Universitas, Yogyakarta, Indonesia    | [128]      |
| Aspergillus sp. HN15-5D                                 |                                           | *Acanthus ilicifolius* (Leaves, Acanthaceae) | Dongzhaiagang Mangrove National Nature Reserve, Hainan Island, China. | [73]       |
| Nectriapyrone A (101)                                   | *Nectria pseudotrichia* 120-1NP           | *Gliricidia sepium* (Stems, Fabaceae)  | Wanagama forest of Universitas, Yogyakarta, Indonesia    | [128]      |
| Nectriapyrone B (102)                                   | *Nectria pseudotrichia* 120-1NP           | *Gliricidia sepium* (Stems, Fabaceae)  | Wanagama forest of Universitas, Yogyakarta, Indonesia    | [128]      |
Table 1. Cont.

| Compound Name                                           | Fungus                          | Host (Part, Family)                           | Source, Place                                                   | References |
|----------------------------------------------------------|---------------------------------|----------------------------------------------|----------------------------------------------------------------|------------|
| 6-O-Methylreticulol (103)                                | Xylariaceae sp. QGS 01          | Quercus gilva Blume (Stems, Fagaceae)        | Ehime University Garden, Ehime Prefecture, Japan                | [102]      |
| 8-Hydroxy-6,7-dimethoxy-3-methylisocoumarin              | Biscogniauxia capnodes          | Xylariaceae sp. QGS 01                       | Ahime University Garden, Ehime Prefecture, Japan                | [102]      |
| 7-Hydroxy-3,5-dimethylisochromen-1-one (104)             | Phoma sp. YE3135                | Aconitum wilmorinianum (Roots, Ranunculaceae) | Yunnan University, China                                        | [26]       |
| 6,8-Dihydroxy-3-hydroxymethylisocoumarin (105)           | Aspergillus versicolor KJ801852 | Myoporum bontioides (Leaves, Scrophulariaceae) | Leizhou Peninsula, China                                        | [71]       |
| Botryospyrone A (106)                                    | Botryosphaeria ramosa L29       | Myoporum bontioides (Leaves, Scrophulariaceae) | Leizhou Peninsula, China                                        | [71]       |
| Botryospyrone B (107)                                    | Botryosphaeria ramosa L29       | Myoporum bontioides (Leaves, Scrophulariaceae) | Leizhou Peninsula, China                                        | [71]       |
| Decarboxyhydroxycitrinone (108)                          | Arthrinium sacchari             | Unidentified sponge                          | The coast of Atami-shi, Shizuoka Prefecture, Japan             | [90]       |
| Tubakialactone A (109)                                   | Tubakia sp. ECN-111             | Houttuynia cordata Thunb (Leaves, Saururaceae) | Chikusa-ku Nagoya city, Japan                                   | [115]      |
| 6,8-Dihydroxy-7-methyl-1-oxo-1H-isochromene-3-carboxylic acid (110) | Pestalotiopsis coffea           | Caragota mitis (Palm, Arecaceae)             | Hainan Province, China                                          | [129]      |
| Oryzaein A (111)                                         | Aspergillus oryzae              | Paris polyphylla var. yunnanensis (Franch. Hand-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China                                             | [94]       |
| Oryzaein B (112)                                         | Aspergillus oryzae              | Paris polyphylla var. yunnanensis (Franch. Hand-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China                                             | [94]       |
| Caudacoumarin C (113)                                    | Aspergillus oryzae              | Paris polyphylla var. yunnanensis (Franch. Hand-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China                                             | [94]       |
| 4,5,7-Trihydroxy-3-methoxy-3,6-dimethylisochroman-1-one (114) | Aspergillus sp. 16-5B           | Sonneratia apetala (Leaves, Lythraceae)      | Dongzhaiagang Mangrove National Nature Reserve in Hainan Island, China | [38]       |
Table 1. Cont.

| Compound Name                                                                 | Fungus            | Host (Part, Family)                                      | Source, Place                                                                 | References |
|-------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|------------------------------------------------------------------------------|------------|
| 5,7-Dihydroxy-3-methoxy-3,6-dimethylisochromane-1,4-dione (115)              | Aspergillus sp. 16-5B | Sonneratia apetala (Leaves, Lythraceae)                  | Dongzhaihang Mangrove National Nature Reserve in Hainan Island, China         | [38]       |
| 3,4-Dihydro-3,6,8-trihydroxy-3,5-dimethylisocoumarin (116)                   | Mycelia sterile 4567 | Canadian thistle Cirsium arvense (Asteraceae)            | Lower Saxony, Germany                                                        | [20]       |
| Tenuissimasatin (117)                                                         | Alternaria tenuissima | Erythrophleum fordii (Barks, Fabaceae)                    | Nanning, Guangxi Province, China                                              | [130]      |
| Penicoffrazin B (118)                                                         | Penicillium coffeae MA-314 | Laguncularia racemose (Leaves, Combretaceae)              | Hainan island, China                                                         | [47]       |
| Penicoffrazin C (119)                                                         | Penicillium coffeae MA-314 | Laguncularia racemose (Leaves, Combretaceae)              | Hainan island, China                                                         | [47]       |
| 6,8-Dihydroxy-3-methoxy-3,7-dimethylisochroman-1-one (120)                   | Pestalotiopsis coffeae | Caryota mitis (Palm, Arecaceae)                          | Hainan Province, China                                                       | [129]      |
| Acremonone B (121)                                                           | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae)          | Satun Province, Thailand                                                     | [125]      |
| Acremonone C (122)                                                           | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae)          | Satun Province, Thailand                                                     | [125]      |
| Acremonone D (123)                                                           | Acremonium sp. PSU-MA70 | Rhizophora apiculata (Branches, Rhizophoraceae)          | Satun Province, Thailand                                                     | [125]      |
| 4-Acetyl-3,4-dihydro-6,8-dihydroxy-3-methoxy-5-methylisocoumarin (124)       | Mycelia sterile 4567 | Canadian thistle Cirsium arvense (Asteraceae)            | Lower Saxony, Germany                                                       | [20]       |
| 4-Acetyl-3,4-dihydro-6,8-dihydroxy-5-methylisocoumarin (125)                 | Mycelia sterile 4567 | Canadian thistle Cirsium arvense (Asteraceae)            | Lower Saxony, Germany                                                       | [20]       |
| Phomolactone A (126)                                                          | Phomopsis sp. 7233  | Laurus azorica (Leaves, Lauraceae)                       | Gomera, Spain                                                               | [42]       |
|                                                                               | Aspergillus versicolor | Paris marmorata Stearn (Rhizomes, Melanthiaceae)       | Dali, Yunnan, China                                                         | [93]       |
| Phomolactone B (127)                                                          | Phomopsis sp. 7233  | Laurus azorica (Leaves, Lauraceae)                       | Gomera, Spain                                                               | [42]       |
|                                                                               | Aspergillus versicolor | Paris marmorata Stearn (Rhizomes, Melanthiaceae)       | Dali, Yunnan, China                                                         | [93]       |
| Phomolactone C (128)                                                          | Phomopsis sp. 7233  | Laurus azorica (Leaves, Lauraceae)                       | Gomera, Spain                                                               | [42]       |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| (3R)-3-hydroxymethyl-8-hydroxy-3,4-dihydroisocoumarin (129) | *Sarcosomataceae* sp. NO.49-14-2-1 | *Eversniastrum nepalense* (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| 8-Methylmellein (130) | *Sarcosomataceae* sp. NO.49-14-2-1 | *Eversniastrum nepalense* (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| | *Pestalotiopsis* sp. HHL101 | *Rhizophora stylosa* (Branches, Rhizophoraceae) | Dong Zhai Gang-Mangrove Garden, Hainan Island, China | [72] |
| Trans-4-hydroxymellein (131) | *Penicillium* sp.1 and sp.2 | *Alibertia macrophylla* (Leaves, Rubiaceae) | Mogi-Guaçu, São Paulo, Brazil | [18] |
| | *Botryosphaeria* sp. KcF6 | *Kandelia candel* (Fruits, Rhizophoraceae), | Daya Bay, Shenzhen, China | [36] |
| | *Sarcosomataceae* sp. NO.49-14-2-1 | *Eversniastrum nepalense* (Taylor) Hale ex Sipman (Lichen, Parmeliaceae) | Panzhihua, Sichuan province, China | [121] |
| | *Lachnum palmae* | *Przewalska tangutica* Maxim. (Leaves, Solanaceae) | Linzhou Country of the Tibet Autonomous Region, China | [51] |
| 3,5-Dimethyl-8-hydroxy-7-methoxy-3,4-dihydroisocoumarin (132) | *Cytospora eucalypticola* SS8 | *Eucalyptus perriniana* (Bark, Myrtaceae) | Royal Botanic Gardens, Kew, United Kingdom | [55] |
| 3,5-dimethyl-8-methoxy-3,4-dihydroisocoumarin (133) | *Cytospora eucalypticola* SS8 | *Eucalyptus perriniana* (Barks, Myrtaceae) | Royal Botanic Gardens, Kew, United Kingdom | [55] |
| | *Cytospora eucalypticola* SS8 | *Eucalyptus perriniana* (Barks, Myrtaceae) | Royal Botanic Gardens, Kew, United Kingdom | [55] |
| (3R)-5-Methylmellein (134) | Centraalbureau voor Schimmel cultures (120379) | *Picea glauca* (Leaves, Pinaceae) | Sussex, New Brunswick, Canada | [119] |
| 3,4-Dihydro-(3R),5-dimethyl-8-hydroxyisocoumarin | *Xylaria* sp. PSU-G12 | *Garcinia hombroniana* (Branches, Clusiaceae) | Songkhla province, Thailand | [95] |
| | *Xylaria cubensis* (Xylariaceae) BCRC 09F 0035 | *Litsea akowsis* Hayata (Leaves, Lauraceae) | Kaohsiung, Taiwan | [109] |
| | *Biscogniauxia capnodes* | *Averrhoa carambola* L. (Fruits, Oxalidaceae) | Home garden in Kandy, Central Province, Sri Lanka | [96] |
Table 1. Cont.

| Compound Name                                      | Fungus                  | Host (Part, Family)          | Source, Place                                      | References |
|-----------------------------------------------------|-------------------------|------------------------------|---------------------------------------------------|------------|
| 5-Hydroxymethylmellein (135)                        | Cytospora eucalypticola SS8 | *Eucalyptus perriniana* (Barks, Myrtaceae) | Royal Botanic Gardens, Kew, United Kingdom        | [55]       |
| 8-Hydroxy-5-hydroxymethyl-3-methyl-3,4-dihydroisocoumarin |                          |                              |                                                   |            |
| 4,8-Dihydroxy-3,5-dimethyl-3,4-dihydroisocoumarin (136) | Cytospora eucalypticola SS8 | *Eucalyptus perriniana* (Barks, Myrtaceae) | Royal Botanic Gardens, Kew, United Kingdom        | [55]       |
| Periplanetin D (137)                                | Aspergillus versicolor  | *Paris maromorta* Stearn (Rhizomes, Melanthiaceae) | Dali, Yunnan, People’s Republic of China,         | [93]       |
|                                                     | *Penicillium oxalicum* 0403 | *Nicotiana sanderae* (Leaves, Solanaceae) | Shilin, Yunnan Province, China                    | [44]       |
|                                                     | Pestalotiopsis coffea  | *Caryota mitis* (Palm, Arecaceae) | Hainan Province, China                            | [129]      |
| Pestalactone C (138)                                | Pestalotiopsis sp.      | *Photinia fraseris* (Leaves, Amygdaloideae) | Nanjing, Jiangsu, China                           | [22]       |
| (4S) (+)-Ascochin (139)                             | Ascochyta sp.           | *Meliotus dentatus* (Whole plant, Fabaceae) | Shores of the Baltic Sea, near Ahrenshoop, Germany | [117]      |
| (4S)-Thielavic acid (140)                           | Thielavia sp. ECN-115   | *Crassula ovata* (Stems, Crassulaceae) | Chikusa-ku Nagoya city, Japan                    | [115]      |
| Phomasatin (141)                                    | Phoma sp. YN02-P-3      | *Sumbaviopsis albicans* J. J. Smith (Leaves, Euphorbiaceae) | Yunnan, China                                    | [84]       |
| 3,4-Dihydro-6-methoxy-8-hydroxy-3,4,5-trimethyl-isocoumarin-7-carboxylic acid methyl ester (142) | Fungus dz17              | Mangrove plant | South China Sea coast, China | [88]       |
| 3,4-Dihydro-4,8-dihydroxy-3,5-dimethylisocoumarin (143) | Fungus dz17              | Mangrove plant | South China Sea coast, China | [88]       |
| 3,4-Dihydro-8-hydroxy-3-methylisocoumarin-5-carboxylic acid (144) | Fungus dz17              | Mangrove plant | South China Sea coast, China | [88]       |
| Pestalotiopisorin B (145)                           | Pestalotiopsis sp. HHL101 | *Rhizophora stylosa* (Branches, Rhizophoraceae) | Dong Zhai Gang-Mangrove Garden, Hainan Island, China | [72]       |
| Pestaloisocoumarin A (146)                          | Pestalotiopsis heterocornis | *Phakellia fusca* (Sponge, Axinellidae) | Xisha Islands, China                             | [75]       |
| Pestaloisocoumarin B (147)                          | Pestalotiopsis heterocornis | *Phakellia fusca* (Sponge, Axinellidae) | Xisha Islands, China                             | [75]       |
Table 1. Cont.

| Compound Name                     | Fungus                          | Host (Part, Family)                   | Source, Place                                      | References |
|-----------------------------------|---------------------------------|---------------------------------------|----------------------------------------------------|------------|
| Tubakialactone C (148)            | Tubakia sp. ECN-111             | Houttuynia cordata Thunb (Leaves, Saururaceae) | Chikusa-ku Nagoya city, Japan                      | [115]      |
| (R)-3,4-Dihydro-4,8-dihydroxy-6-methoxy-4-methyl-3-methylene-1H-2-benzopyran-1-one | Tubakia sp. ECN-111             | Houttuynia cordata Thunb (Leaves, Saururaceae) | Chikusa-ku Nagoya city, Japan                      | [115]      |
| (R)-3,4-dihydro-4-hydroxy-6,8-dimethoxy-4-methyl-3-methylene-1H-2-benzopyran-1-one (149) | Tubakia sp. ECN-111             | Houttuynia cordata Thunb (Leaves, Saururaceae) | Chikusa-ku Nagoya city, Japan                      | [115]      |
| (6,8-dihydroxy-3-methyl-1-oxo-1H-isochromen-4-yl)methyl-3-methylbutanoate (150) | Talaromyces amestolkiae         | Kandelia obovata (Leaves, Rhizophoraceae)     | Zhanjiang, Guangdong Province, China                | [62]       |
| Penicimarin D (151)               | Penicillium sp. MWZ14-4          | Unidentified sponge GX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China                    | [52]       |
| Penicimarin E (152)               | Penicillium sp. MWZ14-4          | Unidentified sponge GX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China                    | [52]       |
| Penicimarin F (153)               | Penicillium sp. MWZ14-4          | Unidentified sponge GX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China                    | [52]       |
| Penicimarin G (154)               | Penicillium citrinum HL-5126     | Bruguiera sexangula var. rhynchopetala (Roots, Rhizophoraceae) | Hainan Island, P.R. China                          | [56]       |
| Penicimarin H (155)               | Penicillium citrinum HL-5126     | Bruguiera sexangula var. rhynchopetala (Roots, Rhizophoraceae) | Hainan Island, China                               | [56]       |
| Penicimarin I (156)               | Penicillium citrinum HL-5126     | Bruguiera sexangula var. rhynchopetala (Roots, Rhizophoraceae) | Hainan Island, China                               | [56]       |
| Penicisimpin A (157)              | Penicillium simplicissimum MA-332 | Bruguiera sexangula var. rhynchopetala (Roots, Rhizophoraceae) | Hainan Island, China                               | [58]       |
Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Penicisimpin B (158) 3-(R)-6,8-Dihydroxy-3-pentylisochroman-1-one | *Penicillium simplicissimum* MA-332 | *Bruguiera sexangula* var. rhynchocarpa (Roots, Rhizophoraceae) | Hainan Island, China | [58] |
| Penicisimpin C (159) 3-(S)-6,8-Dihydroxy-7-methyl-3-(pent-1-enyl)isochroman-1-one | *Penicillium simplicissimum* MA-332 | *Bruguiera sexangula* var. rhynchocarpa (Roots, Rhizophoraceae) | Hainan Island, China | [58] |
| Fusarentin 6-methyl ether (160) | Colletotrichum sp. CRI535-02 | *Piper ornatum* (Leaves, Piperaceae) | Tai Rom Yen National Park, Surat Thani Province, Thailand | [80] |
| Fusarentin 6,7-dimethyl ether (161) | Colletotrichum sp. CRI535-02 | *Piper ornatum* (Leaves, Piperaceae) | Tai Rom Yen National Park, Surat Thani Province, Thailand | [80] |
| 7-Butyl-6,8-dihydroxy-3(R)-pent-11-enylisochroman-1-one (162) | *Geotrichum* sp. | *Crassocephalum crepidioides* S. Moore (Stems, Asteraceae) | Songkhla Province, Southern Thailand | [74] |
| 7-But-15-enyl-6,8-dihydroxy-3(R)-pent-11-enylisochroman-1-one (163) | *Geotrichum* sp. | *Crassocephalum crepidioides* S. Moore (Stems, Asteraceae) | Songkhla Province, Southern Thailand | [74] |
| 7-Butyl-6,8-dihydroxy-3(R)-pentylisochroman-1-one (164) | *Geotrichum* sp. | *Crassocephalum crepidioides* S. Moore (Stems, Asteraceae) | Songkhla Province, Southern Thailand | [74] |
| Monocerin (165) | *Microdochium bolleyi* 8880 | *Fagonia cretica* (Leaves, Zygophyllaceae) | Gomera, Spain. | [49] |
| | *Exserohilum rostratum* EU571210 | *Stemona* sp. (Leaves and roots, Stemonaceae) | Amphur Bangban, Ayutthaya Province, Thailand | [46] |
| | Colletotrichum sp. CRI535-02 | *Piper ornatum* (Leaves, Piperaceae) | Tai Rom Yen National Park, Surat Thani Province, Thailand | [80] |
| | Botryosphaeria sp. KcF6 | *Kandelia candel* (Fruits, Rhizophoraceae) | Daya Bay, Shenzhen, China | [36] |
| | *Exserohilum rostratum* ER1.1 | *Bauhinia guianensis* (Fabaceae) | Embrapa Amazônia Oriental Belém, Brazil | [59] |
| | Leptosphaena maculans | *Osmanthus fragrans* (Leaves, Oleaceae) | China | [104] |
| Compound Name          | Fungus                  | Host (Part, Family)                  | Source, Place                                                | References |
|------------------------|-------------------------|--------------------------------------|--------------------------------------------------------------|------------|
| 7-O-Demethylmonocerin (166) | *Colletotrichum* sp. CRI35-02 | *Piper ornatum* (Leaves, Piperaceae) | Tai Rom Yen National Park, Surat Thani Province, Thailand | [80]       |
|                        | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Xuwen, Guangdong Province, China | [64]       |
| (12R)-Hydroxymonocerin (167) | *Microdochium bolleyi* 8880 | *Fagonia cretica* (Leaves, Zygophyllaceae) | Gomera, Spain | [49]       |
|                        | *Exserohilum* sp. KJ156361 | *Acer truncatum* (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China. | [60]       |
|                        | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Guangdong Province, China | [64]       |
|                        | *Leptosphaena maculans* | *Osmanthus fragrans* (Leaves, Oleaceae) | China | [104]       |
| (11R)-Hydroxymonocerin (168) | *Exserohilum rostratum* EU571210 | *Stemona* sp. (Leaves and roots, Stemonaceae) | Amphur Bangban, Ayutthaya Province, Thailand | [46]       |
|                        | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Guangdong Province, China | [64]       |
| (12S)-Hydroxymonocerin (169) | *Microdochium bolleyi* 8880 | *Fagonia cretica* (Leaves, Zygophyllaceae) | Gomera, Spain. | [49]       |
| Exserolide D (170) | *Exserohilum* sp. KJ156361 | *Acer truncatum* (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China. | [60]       |
|                        | *Aspergillus oryzae* | *Paris polyphylla* var. yunnanensis (Franch.) Hand.-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China | [94]       |
| Exserolide E (171) | *Exserohilum* sp. KJ156361 | *Acer truncatum* (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China. | [60]       |
|                        | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Guangdong Province, China | [64]       |
| Exserolide I (172) | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Guangdong Province, China | [64]       |
| Exserolide J (173) | *Setosphaeria* sp. SCSIO41009 | *Callyspongia* sp. (Sponge, Callyspongiidae) | Guangdong Province, China | [64]       |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|--------------|------------|
| Maculansline D (174) Isomer of (12R)-12-hydroxymonocerin | Leptosphaena maculans | Osmanthus fragrans (Leaves, Oleaceae) | China | [104] |
| Exserolide A (175) | Exserohilum sp. KJ156361 | Acer truncatum (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China. | [60] |
| Exserolide B (176) | Exserohilum sp. KJ156361 | Acer truncatum (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China. | [60] |
| | Setosphaeria sp. SCSIO41009 | Callyspongia sp. (Sponge, Callyspongiiidae) | Guangdong Province, China | [64] |
| Exserolide C (177) | Exserohilum sp. KJ156361 | Acer truncatum (Leaves, Sapindaceae) | Dongling Mountain, Beijing, China | [60] |
| | Setosphaeria sp. SCSIO41009 | Callyspongia sp. (Sponge, Callyspongiiidae) | Guangdong Province, China | [64] |
| Exserolide K (178) | Setosphaeria sp. SCSIO41009 | Callyspongia sp. (Sponge, Callyspongiiidae) | Guangdong Province, China | [64] |
| Pestalactone A (179) | Pestalotiopsis sp. | Photinia frasery (Leaves, Amygdaloideae) | Nanjing, Jiangsu, China | [22] |
| Pestalactone B (180) | Pestalotiopsis sp. | Photinia frasery (Leaves, Amygdaloideae) | Nanjing, Jiangsu, China | [22] |
| 8-Dihydroramulosin (181) | Nigrospora sp. PSU-N24 | Garcinia nigrolineata (Branches, Clusiaceae) | Ton Nga Chang wildlife sanctuary, Songkhla province, Southern Thailand | [110] |
| | Nigrospora sp. LLGLM003 | Moringa oleifera (Roots, Moringaceae) | Xiamen municipality, Fujian Province, China | [53] |
| 6β-Hydroxy-8-dihydroramulosin (182) | Nigrospora sp. PSU-N24 | Garcinia nigrolineata (Branches, Clusiaceae) | Ton Nga Chang wildlife sanctuary, Songkhla province, Southern Thailand | [110] |
| (−) Ramulosin (183) | Talaromyces sp. JQ769262 | Cedrus deodara (Twigs, Pinaceae) | Lolab Valley in the Western Himalayas, Kashmir, India | [83] |
| (3S,4aR,7S)-7,8-Dihydroxy-3-methyl-3,4,10,5,6,7-hexahydro-1H-isochromen-1-one (184) | Talaromyces sp. JQ769262 | Cedrus deodara (Twigs, Pinaceae) | Lolab Valley in the Western Himalayas, Kashmir, India | [83] |
Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| 6-Hydroxyramulosin (185) | Nigrospora sp. PSU-N24 | *Garcinia nigrolineata* (Branches, Clusiaceae) | Ton Nga Chang wildlife sanctuary, Songkhla province, Southern Thailand | [110] |
| Peniciisocoumarin A (186) | Penicillium sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Peniciisocoumarin B (187) | Penicillium sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Alternariol (188) | *Alternaria* sp. II2L4 | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt | [40] |
| Alternariol-5-O-methyl ether (189) | *Alternaria* tenuissima SP-07 | *Salvia przewalskii* (Roots, Lamiaceae) | Longxi County, Gansu Province, China | [57] |
| Alternariol-5-O-methyl ether (189) | *Alternaria* alternata | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China | [63] |
| Alternariol-5-O-methyl ether (189) | *Peyronellaea glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| Alternariol-5-O-methyl ether (189) | *Alternaria* sp. II2L4 | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt | [40] |
| Alternariol-5-O-methyl ether (189) | *Alternaria* tenuissima SP-07 | *Salvia przewalskii* (Roots, Lamiaceae) | Longxi County, Gansu Province, China | [57] |
| Alternariol-5-O-methyl ether (189) | *Alternaria* alternata | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China | [63] |
| Alternariol-5-O-methyl ether (189) | *Peyronellaea glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| 3′-Hydroxylalternariol 5-O-methyl ether (190) | *Alternaria* sp. II2L4 | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt | [40] |
| Alternariol 5-O-sulfate (191) | *Alternaria* sp. II2L4 | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt | [40] |
| Alternariol 5-O-methyl ether-4′-O-sulfate (192) | *Alternaria* sp. II2L4 | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt | [40] |
| Compound Name                              | Fungus                     | Host (Part, Family)                      | Source, Place                          | References |
|-------------------------------------------|----------------------------|-----------------------------------------|----------------------------------------|------------|
| Altenuene (193)                           | *Alternaria* sp. II2L4     | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt                      | [40]       |
|                                           | *Alternaria tenuissima* SP-07 | *Salvia przewalskii* (Roots, Lamiaceae) | Longxi County, Gansu Province, China  | [57]       |
|                                           | *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
| (−)-(2R,3R,4aR)-Altenuene-2-acetoxy ester | *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
| (+)-(2S,3S,4aS)-Altenuene-2-acetoxy ester| *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
| (−)-(2R,3R,4aR)-Altenuene-3-acetoxy ester| *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
| (+)-(2S,3S,4aS)-Altenuene-3-acetoxy ester| *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
| 5′-Epialtenuene (196)                     | *Alternaria alternata*     | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China      | [63]       |
|                                           | *Alternaria* sp. II2L4     | *Polygonum senegalense* Meisn. (Leaves, Polygonaceae) | Alexandria, Egypt                      | [40]       |
| Cycloepoxylactone (197)                   | *Phomopsis* sp. 7233       | *Laurus azorica* (Leaves, Lauraceae)    | Gomera, Spain                          | [42]       |
| EI-1941-2 (198)                           | *Phomopsis* sp. 7233       | *Laurus azorica* (Leaves, Lauraceae)    | Gomera, Spain                          | [42]       |
| Cycloepoxytriol A (199)                   | *Phomopsis* sp. 7233       | *Laurus azorica* (Leaves, Lauraceae)    | Gomera, Spain                          | [42]       |
| Cycloepoxytriol B (200)                   | *Phomopsis* sp. 7233       | *Laurus azorica* (Leaves, Lauraceae)    | Gomera, Spain                          | [42]       |
| Exserolide F (201)                        | *Esseohilum* sp. KJ156361 | *Acer truncatum* (Leaves, Sapindaceae)  | Dongling Mountain, Beijing, China     | [60]       |
|                                           | *Aspergillus oryzae*       | *Paris polyphylla var. yunnanensis* (Franch.) Hand.-Mazz. (Rhizomes, Liliaceae) | Dali, Yunnan, China                   | [94]       |
| Isocitreoisocoumarinol (202)              | *Peyronella glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65]       |
| (+)-Citreoisocoumarin (203)               | *Ampelomyces* sp. EU143251 | *Urospernum picroides* (Flowers, Asteraceae) | Alexandria, Egypt                     | [39]       |
|                                           | *Peyronella glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65]       |
| Compound Name                  | Fungus                                   | Host (Part, Family)            | Source, Place                                      | References |
|-------------------------------|------------------------------------------|--------------------------------|---------------------------------------------------|------------|
| (+)-Citreoisoumarin (203)     | *Nectria* sp. HN001                      | *Sonneratia ovata* (Branches, Lythraceae) | South China Sea in Hainan province, China         | [33]       |
|                               | *Phoma* sp. TA07-1                       | *Dichotella gemmacea*          | Weizhou coral reef, South China Sea, China        | [131]      |
|                               | *Ascomycota* sp. CYSK-4                  | *Pluchea indica* (Branches, Asteraceae) | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37]       |
| (+)-6-Methylcitreoisoumarin (204) | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. sponge (Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
|                               | *Penicillium commune* QPF-3              | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China                          | [31]       |
| Citreoisoumarinol (205)       | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
|                               | *Nectria* sp. HN001                      | *Sonneratia ovata* (Branches, Lythraceae) | South China Sea, Hainan province, China           | [33]       |
|                               | *Phoma* sp. (TA07-1)                     | *Dichotella gemmacea*          | Weizhou coral reef, South China Sea, China        | [131]      |
| 12-epicitreoisoumarinol (206) | *Nectria* sp. HN001                      | *Sonneratia ovata* (Branches, Lythraceae) | South China Sea, Hainan province, China           | [33]       |
| Mucorisoumarin A (207)        | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
| Mucorisoumarin B (208)        | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
|                               | *Ascomycota* sp. CYSK-4                  | *Pluchea indica* (Branches, Asteraceae) | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37]       |
| Peyroisoumarin A (209)        | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
| Peyroisoumarin B (210)        | *Peyronellaea* glomerata XSB-01-15       | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China            | [65]       |
| Compound Name                  | Fungus               | Host (Part, Family)                          | Source, Place                        | References |
|-------------------------------|----------------------|----------------------------------------------|--------------------------------------|------------|
| Peyroisocoumarin C (211)      | Peyronellaea glomerata XSB-01-15 | Amphimedon sp. (Sponge, Niphatidae)           | Yongxin Island, Hainan Province, China | [65]       |
| Aspergillumarin A (212)       | Aspergillus sp.       | Bruguiera gymnorrhiza (Leaves, Rhizophoraceae) | South China Sea coast, China          | [61]       |
|                               | Penicillium sp. (MWZ14-4) | Unidentified spongeGX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China       | [52]       |
| Talaromyces amestolkiae       | Kandelia obovata (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China          | [62]       |
| Penicillium citrinum          | Bruguiera sexangula var. rynchopetala (Roots, Rhizophoraceae) | Hainan Island, China                      | [56]       |
| HL-5126                       | Penicillium sp. TGM112 | Bruguiera sexangula var. rynchopetala (Leaves, Rhizophoraceae) | South China Sea, China               | [67]       |
| Aspergillumarin B (213)       | Aspergillus sp.       | Bruguiera gymnorrhiza (Leaves, Rhizophoraceae) | South China Sea, China               | [61]       |
| Penicillium sp. (MWZ14-4)     | Unidentified spongeGX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China            | [52]       |
| Talaromyces amestolkiae       | Kandelia obovata (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China         | [62]       |
| Penicilmarin B (214)          | Penicillium sp. (MWZ14-4) | Bruguiera gymnorrhiza (Leaves, Rhizophoraceae) | South China Sea, China               | [52]       |
| Talaromyces amestolkiae       | Kandelia obovata (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China         | [62]       |
| Penicilmarin C (215)          | Penicillium sp. (MWZ14-4) | Bruguiera gymnorrhiza (Leaves, Rhizophoraceae) | South China Sea, China               | [52]       |
| Talaromyces amestolkiae       | Kandelia obovata (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China         | [62]       |
| Penicilmarin C (215)          | Penicillium sp. TGM112 | Bruguiera sexangula var. rynchopetala (Leaves, Rhizophoraceae) | South China Sea, China               | [67]       |
### Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| (R)-3-((R)-4,5-Dihydroxypentyl)-8-hydroxyisochroman-1-one (216) | *Talaromyces amestolkiae* | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| 5,6-Dihydroxy-3-(4-hydroxypentyl)isochroman-1-one (217) | *Talaromyces amestolkiae* | *Kandelia obovata* (Leaves, Rhizophoraceae) | Zhanjiang, Guangdong Province, China | [62] |
| Maculansline C (218) | *Leptosphaena maculans* | *Osmanthus fragrans* (Leaves, Oleaceae) | China | [104] |
| 3S, 10S-Dihydroisocoumarin, (Epimer) | *Amelomyces* sp. EU143251. | *Urospermum picroides* (Flowers, Asteraceae) | Alexandria, Egypt | [39] |
| | *Phoma* sp. (TA07-1) | *Dichotella gemmacea* GX-WZ-2008003-4 (Gorgonian, Plexauridae) | Weizhou coral reef, South China Sea, China | [131] |
| Desmethyldiaportinol (219) | *Trichoderma* sp. 09 | *Myoporum bontoioides* (Roots, Scrophulariaceae) | Leizhou Peninsula, Guangdong Province, China | [66] |
| Dichlorodiaportin (220) | *Trichoderma* sp. 09 | *Myoporum bontoioides* (Roots, Scrophulariaceae) | Leizhou Peninsula, Guangdong Province, China | [66] |
| | *Ascomyota* sp. CYSK-4 | *Pluchea indica* (Branches, Asteraceae) | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37] |
| | *Aspergillus* sp. HN15-5D | *Acanthus ilicifolius* (Leaves, Acanthaceae) | Dongzhaiagang Mangrove National Nature Reserve, Hainan Island, China | [73] |
| Desmethyldichlorodiaportin (221) | *Amelomyces* sp. EU143251. | *Urospermum picroides* (Flowers, Asteraceae) | Alexandria, Egypt | [39] |
| Peniisocoumarin D (222) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruit, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniisocoumarin E (223) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniisocoumarin F (224) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniisocoumarin G (225) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
### Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Peniisocoumarin H (226) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniisocoumarin I (227) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniisocoumarin J (228) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| 3-[(R)-3,3-Dichloro-2-hydroxypropyl]-8-hydroxy-6-methoxy-1H-isochromen-1-one (229) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| (+)-Diaporthin (230) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Diaportinol (231) | *Peyronellaea glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| | *Trichoderma* sp. 09 | *Myoporum bottoides* (Roots, Scrophulariaceae) | Leizhou Peninsula, Guangdong Province, China | [66] |
| | *Phoma* sp. (TA07-1) | *Dichotella gemmacea* GX-WZ-2008003-4 (Gorgonian, Plexauridae) | Weizhou coral reef, South China Sea, China | [131] |
| | *Ascomycota* sp. CYSK-4 | *Pluchea indica* (Branches, Asteraceae) | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37] |
| (+)-(10R)-7-Hydroxy-3-(2-hydroxy-propyl)-5,6-dimethylisochromen-1-one (232) | *Alternaria alternata* | *Camellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China | [63] |
| Peyroisocoumarin D (233) | *Peyronellaea glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| Orthosporin (234) | *Peyronellaea glomerata* XSB-01-15 | *Amphimedon* sp. (Sponge, Niphatidae) | Yongxin Island, Hainan Province, China | [65] |
| 8-Methyl-11-chlorodiaporthin (235) | *Aspergillus* sp. CPCC 400810 | *Cetreria* sp. (Lichen, Parmeliaceae) | Laojun Mount in Yunnan Province, China | [29] |
| 8-Methyl-11,11-dichlorodiaporthin (236) | *Aspergillus* sp. CPCC 400810 | *Cetreria* sp. (Lichen, Parmeliaceae) | Laojun Mount in Yunnan Province, China | [29] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| 8-Hydroxy-6-methoxy-3-(2,3,3-trihydroxypropyl)-1H-isochromen-1-one (237) | *Penicillium faniculosum* Fes1711 | *Ficus elastica* (Leaves, Moraceae) | Liaocheng University Arboretum, Liaocheng, Shandong, China | [69] |
| 8-Hydroxy-6-methoxy-3-(1,2,3-trihydroxypropyl)-1H-isochromen-1-one (238) | *Penicillium faniculosum* Fes1711 | *Ficus elastica* (Leaves, Moraceae) | Liaocheng University Arboretum, Liaocheng, Shandong, China | [69] |
| Aspergisocoumarin C (239) | *Aspergillus* sp. HN15-5D | *Acanthus ilicifolius* (Leaves, Acanthaceae) | Dongzhaigang Mangrove National Nature Reserve, Hainan Island, China | [73] |
| (3R,4R,10R)-Fusarentin 4-hydroxy-6,7-dimethyl ether (240) | *Microdochium bolleyi* 8880 | *Fagonia cretica* (Leaves, Zygophyllaceae) | Gomera, Spain | [49] |
| Colletostrichum sp. CRI535-02 | *Piper ornatum* (Leaves, Piperaceae) | Tai Rom Yen National Park, Surat Thani Province, Thailand | [80] |
| Colletomellein A (241) | *Colletotrichum aotearoa* BCRC 09F0161 | *Bredia oldhamii* Hook. f. (Leaves, Melastomataceae) | Mutan, Pingtung County, Taiwan | [132] |
| Colletomellein B (242) | *Colletotrichum aotearoa* BCRC 09F0161 | *Bredia oldhamii* Hook. f. (Leaves, Melastomataceae) | Mutan, Pingtung County, Taiwan | [132] |
| Peniciisocoumarin D (243) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Peniciisocoumarin F (244) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Peniciisocoumarin H (245) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| 3,4-Dihydro-8-hydroxy-6-methoxy-(3R)-propylisocoumarin (246) | Centraalbureau voor Schimmel cultures (120379) | *Picea glauca* (Leaves, Pinaceae) | Sussex, New Brunswick, Canada | [119] |
| Peniciisocoumarin C (247) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Peniciisocoumarin E (248) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Peniciisocoumarin G (249) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| (R)-3-(3-Hydroxypropyl)-8-hydroxy-3,4-dihydroisocoumarin (250) | *Penicillium* sp. TGM112 | *Bruguiera sexangula* var. rhynchopetala (Leaves, Rhizophoraceae) | South China Sea, China | [67] |
| Versicoumarin A (251) | *Aspergillus versicolor* | *Paris marmorata* Stearn (Rhizomes, Melanthiaceae) | Dali, Yunnan, China | [93] |
| Versicoumarin D (252) | *Aspergillus versicolor* | *Paris marmorata* Stearn (Rhizomes, Melanthiaceae) | Dali, Yunnan, China | [89] |
| Paraphaeosphaerin A (253) | *Paraphaeosphaeria quadriseptata* | *Opuntia leptocaulis* (Rhizosphere, Cactaceae) | Tucson, Arizon | [133] |
| Paraphaeosphaerin B (254) | *Paraphaeosphaeria quadriseptata* | *Opuntia leptocaulis* (Rhizosphere, Cactaceae) | Tucson, Arizon, America | [133] |
| Chaetochiversin A (255) | *Chaetomium chiversii* | *Ephedra fasciculata* (Stems, Ephedraceae) | South mountain park, Phoenix, Arizona, America | [133] |
| Chaetochiversin B (256) | *Chaetomium chiversii* | *Ephedra fasciculata* (Stems, Ephedraceae) | South mountain park, Phoenix, Arizona, America | [133] |
| Paraphaeosphaerin C (257) | *Paraphaeosphaeria quadriseptata* | *Opuntia leptocaulis* (Rhizosphere, Cactaceae) | Tucson, Arizon, America | [133] |
| Peniiisocoumarin C (258) | *Penicillium commune* QQF-3 | *Kandelia candel* (Fruits, Rhizophoraceae) | Guangdong Province, China. | [31] |
| 6,6′-Dinor-bipenicilisorin (259) | *Aspergillus versicolor* KU258497 | *Eichhornia crassipes* (Leaves, Pontederiaceae) | Mansoura, Egypt | [81] |
| 6,6′,9′-Trinor-bipenicilisorin (260) | *Aspergillus versicolor* KU258497 | *Eichhornia crassipes* (Leaves, Pontederiaceae) | Mansoura, Egypt | [81] |
| Asperisocoumarin A (261) | *Aspergillus sp.* 085242 | *Acanthus ilicifolius* (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Asperisocoumarin B (262) | Aspergillus sp. 085242 | Acanthus ilicifolius (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
| Asperisocoumarin C (263) | Aspergillus sp. 085242 | Acanthus ilicifolius (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
| Asperisocoumarin D (264) | Aspergillus sp. 085242 | Acanthus ilicifolius (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
| Asperisocoumarin E (265) | Aspergillus sp. 085242 | Acanthus ilicifolius (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
| Asperisocoumarin F (266) | Aspergillus sp. 085242 | Acanthus ilicifolius (Roots, Acanthaceae) | Shankou Mangrove National Nature Reserve, Guangxi Province, China | [76] |
| Peniiisocoumarin A (267) | Penicillium commune QF-3 | Kandelia candel (Fruit, Rhizophoraceae) | Guangdong Province, China | [31] |
| Peniiisocoumarin B (268) | Penicillium commune QF-3 | Kandelia candel (Fruits, Rhizophoraceae) | Guangdong Province, China | [31] |
| Sg17-1-4 (269) | Alternaria tenuis Sg17-1 | Marine alga | Zhoushan Island, Zhejiang Province, China | [85] |
| AI-77-B (270) | Alternaria tenuis Sg17-1 | Marine alga | Zhoushan Island, Zhejiang Province, China | [85] |
| AI-77-F (271) | Alternaria tenuis Sg17-1 | Marine alga | Zhoushan Island, Zhejiang Province, China | [85] |
| Similanpyrone A (272) | Aspergillus similansens sp. nov. KUFA 0013 | Rhabdermia sp. (Sponge, Rhabderemidae) | Phang Nga Province, Thailand | [48] |
| Similanpyrone C (273) | Aspergillus similansens KUFA 0013 | Rhabdermia sp. (Sponge, Rhabderemidae) | Phang Nga Province, Thailand | [28] |
| Aspergisocoumarin A (274) | Aspergillus sp. HN15-5D | Acanthus ilicifolius (Leaves, Acanthaceae) | Dongzhaiagang Mangrove National Nature Reserve, Hainan Island, China | [73] |
| Aspergisocoumarin B (275) | Aspergillus sp. HN15-5D | Acanthus ilicifolius (Leaves, Acanthaceae) | Dongzhaiagang Mangrove National Nature Reserve, Hainan Island, China | [73] |
| Dothideomynone A (276) | Aspergillus banksianus sp. nov | Banksia integrifolia (Leaves, Proteaceae) | Collaroy, New South Wales, Australia | [30] |
| Compound Name                  | Fungus                                      | Host (Part, Family)                      | Source, Place                                           | References |
|-------------------------------|---------------------------------------------|------------------------------------------|---------------------------------------------------------|------------|
| Banksialactone A (277)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone F (278)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone E (279)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone B (280)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone C (281)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone D (282)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone G (283)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone H (284)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Banksialactone I (285)        | *Aspergillus banksianus* sp. nov            | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia                     | [30]       |
| Demethylcitreoviranol (286)   | *Peyronellaea glomerata* XSB-01-15          | *Amphimedon* sp. (Sponge, Niphatidae)     | Yongxin Island, Hainan Province, China                   | [65]       |
| Citreoviranol (287)           | *Peyronellaea glomerata* XSB-01-15          | *Amphimedon* sp. (Sponge, Niphatidae)     | Yongxin Island, Hainan Province, China                   | [65]       |
| Desmethyl dichlorodiaportinol (288) | *Ascomycota* sp. CYSK-4                      | *Pluchea indica* (Branches, Asteraceae)   | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37]       |
| Dichlorodiaportinol A (289)   | *Trichoderma* sp., 09                       | *Myoporum bontioides* (Roots, Scrophulariaceae) | Leizhou Peninsula, Guangdong Province, China            | [79]       |
| Dichlorodiaportinolide (290)  | *Trichoderma* sp. 09                        | *Myoporum bontioides* (Roots, Scrophulariaceae) | Leizhou Peninsula, Guangdong Province, China            | [66]       |
| Dichlorodiaportintone (291)   | *Ascomycota* sp. CYSK-4                     | *Pluchea indica* (Branches, Asteraceae)   | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37]       |
| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| Desmethyldichlorodiaportintone (292) | *Ascomycota* sp. CYSK-4 | *Pluchea indica* (Branches, Asteraceae) | Shankou Mangrove Nature Reserve, Guangxi Province, China | [37] |
| Botryoisocoumarin A (293) 3S-5,8-dihydroxy-3-hydroxymethyldihydroisocoumarin | *Botryosphaeria* sp. KcF6 | *Kandelia candel* (Fruits, Rhizophoraceae) | Daya Bay, Shenzhen, China | [36] |
| Clearanol I (294) | *Aspergillus banksianus* sp. nov. | *Banksia integrifolia* (Leaves, Proteaceae) | Collaroy, New South Wales, Australia | [30] |
| Penicimarin A (295) | *Penicillium* sp. MWZ14-4 | Unidentified sponge GX-WZ-2008001 (Inner fresh tissues) | Weizhou, South China Sea, China | [52] |
| Isocoumarindole A (296) | *Aspergillus* sp. CPCC400810 | *Cetraria* sp. (Lichen, Parmeliaceae) | Laojun Mount in Yunnan Province, China | [29] |
| Prochaetoviridin A (297) | *Chaetomium globosum* CDW7 (Chaetomiaceae) | *Ginkgo biloba* (Ginkgoaceae) | Jiangsu province, China | [77] |
| Fusariumin (298) | *Fusarium* sp. LN-10 | *Melia azedarach* (Leaves, Meliaceae) | Campus of Northwest A&F University, Yangling, Shaanxi province, China, | [86] |
| Phialophoriol (299) | Alternaria alternata | *Canellia sinensis* (Branches, Theaceae) | Nanjing, Jiangsu Province, China | [63] |
| (3aR,9bR)-6,9b-Dihydroxy-8-methoxy-1-methylcyclopentene[c]isochromen-3,5-dione (300) | *Penicillium* sp. | *Riccardia multifida* (L.) S. Gray (Liverwort, Aneuraceae) | Maoer Mountain, Guangxi Province, China | [116] |
| (3S,4S)-Dihydroascochin (301) | *Phomopsis* sp. 7233 | *Laurus azorica* (Leaves, Lauraceae) | Gomera, Spain | [42] |
| 3-Methoxy-6,8-dihydroxy-3-methyl-3,4-dihydroisocoumarin (302) | *Penicillium coffeae* MA-314 | *Laguncularia racemosa* (Leaves, Combretaceae) | Hainan island, China | [47] |
| Cis-4,6-Dihydroxymellein (303) | *Penicillium coffeae* MA-314 | *Laguncularia racemosa* (Leaves, Combretaceae) | Hainan island, China | [47] |
| 3,4-Dihydro-8-hydroxyisocoumarin-3-carboxylic methyl ether (304) | *Seltsamia galinsogisoli* sp. nov. SYPF 7336 | *Galinsoga parviflora* (Whole plant, Asteraceae) | Huludao, China | [78] |
### Table 1. Cont.

| Compound Name | Fungus | Host (Part, Family) | Source, Place | References |
|---------------|--------|---------------------|---------------|------------|
| 3-Hydroxymethyl-6,8-dimethoxycoumarin (305) | Endophytic fungus No. GX4-1B | *Bruguiera gymnorrhiza* (L.) Savigny (Branches, Rhizophoraceae) | South China Sea, Guangxi province, China | [127] |
| 1H-2-Benzopyran-1-one,6,8-dihydroxy-3-(2-hydroxypropyl) (306) | *Seltsamia galinsogisoli* sp. nov. SYPF 7336 | *Galinsoga parviflora* (Whole plant, Asteraceae) | Huludao, China | [78] |
| 6,8-Dihydroxy-3-hydroxymethyl-1H-2-benzopyran-1-one (307) | *Penicillium coffeae* MA-314 | *Laguncularia racemose* (Leaves, Combretaceae) | Hainan island, China | [47] |

### Table 2. Biological activities of the most active fungal isocoumarins.

| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| Kigelin (1) (−)-(3R)-6,7-Dimethoxymellein | Antifungal | Agar tube dilution/*Trichophyton longisus* | 45 (% Inhibition) | Miconazole 70 (% Inhibition) | [68] |
| | Antifungal | Agar tube dilution/*A. flavus* | 20 (% Inhibition) | Ampicillin 20 (% Inhibition) | [68] |
| | Antifungal | Agar tube dilution/*Microsporum canis* | 50 (% Inhibition) | Miconazole 98.4 (% Inhibition) | [68] |
| (3R,4R)-6,7-Dimethoxy-4-hydroxymellein (2) | Antifungal | Agar tube dilution/*Trichophyton longisus* | 70 (% Inhibition) | Miconazole 70 (% Inhibition) | [68] |
| | Antifungal | Agar tube dilution/*Microsporum canis* | 50 (% Inhibition) | Miconazole 98.4 (% Inhibition) | [68] |
| | Antifungal | Agar tube dilution/*Fusarium solani* | 20 (% Inhibition) | Miconazole 73.2 (% Inhibition) | [68] |
| | Antioxidant | XO Inhibition | 707 µM (IC<sub>50</sub>) | PG 628 µM (IC<sub>50</sub>) BHA 591 µM (IC<sub>50</sub>) | [68] |
| Cis-4-Acetoxyoxymellein (4) | Antibacterial | Agar diffusion/*E. coli* | 10 mm (GI) | Penicillin 14 mm (GI) Tetracycline 18 mm (GI) | [50] |
| | Antibacterial | Agar diffusion/*Bacillus megaterium* | 10 mm (GI) | Penicillin 18 mm (GI) Tetracycline 18 mm (GI) | [50] |
Table 2. Cont.

| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| Cis-4- Acetoxyoxymellein (4) | Antifungal | Agar diffusion/Microbotryum violaceum | 8 mm (GI) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [50] |
| | Antifungal | Agar diffusion/Septoria tritici | 8 mm (IZD) | | [50] |
| | Algicidal | Agar diffusion/Chlorella fusca | 7 mm (IZD) | Actidione 35 mm (IZD) | [50] |
| 8-Deoxy-6-hydroxy-cis-4-acetoxyoxymellein (5) | Antibacterial | Agar diffusion/E. coli | 9 mm (GI) | Penicillin 14 mm (GI) Tetracycline 18 mm (GI) | [50] |
| | Antibacterial | Agar diffusion/Bacillus megaterium | 9 mm (GI) | Penicillin 18 mm (GI) Tetracycline 18 mm (GI) | [50] |
| | Antifungal | Agar diffusion/Microbotryum violaceum | 8 mm (GI) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [50] |
| | Antifungal | Agar diffusion/Septoria tritici | 9 mm (IZD) | | [50] |
| Algicidal | Agar diffusion/Chlorella fusca | 8 mm (IZD) | Actidione 35 mm (IZD) | [50] |
| (3R,4R)-(-)-4-Hydroxymellein (3R,4R)-Cis-4-Hydroxymellein (6) | Antibacterial | Agar diffusion/Bacillus megaterium | 6 mm (GI) | Penicillin 14 mm (GI) Tetracycline 18 mm (GI) | [43] |
| | Antifungal | Agar diffusion/Microbotryum violaceum | 8 mm (IZD) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [43] |
| | Algicidal | Agar diffusion/Chlorella fusca | 9 mm (IZD) | Actidione 35 mm (IZD) | [43] |
| (-)-6-Methoxymellein (11) | Antiviral | CPE inhibition/H1N1 virus | 20.98 µg/mL (IC₅₀) | Arbidol 0.15 µg/mL (IC₅₀) | [26] |
| Botryospyrone C (13) | Antifungal | 2-Fold broth dilution method/F. oxysporum | 223 µM (MIC) | Triadimefon 340 µM (MIC) | [71] |
| | Antifungal | 2-Fold broth dilution method/F. graminearum | 223 µM (MIC) | Triadimefon 510.7 µM (MIC) | [71] |
| 6-(4′-Hydroxy-2′-methyl phenoxy)-(−)-(3R)-mellein (16) | Antifungal | Agar tube dilution/Trichophyton longifusus | 55 (% Inhibition) | Miconazole 70 (% Inhibition) | [68] |
| Compound Name                                                                 | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control                  | References |
|-------------------------------------------------------------------------------|---------------------|--------------------------------|-------------------|----------------------------------|------------|
| 6-(4′-Hydroxy-2′-methyl phenoxy)-(−)-(3R)-mellein (16)                       | Antifungal          | Agar tube dilution/Microsporum canis | 70 (% Inhibition) | Miconazole 98.4 (% Inhibition)    | [68]       |
|                                                                               | Antifungal          | Agar tube dilution/Fusarium solani  | 30 (% Inhibition) | Miconazole 73.2 (% Inhibition)    | [68]       |
|                                                                               | Antioxidant         | DPPH                            | 159 µM (IC₅₀)    | PG 30 159 µM (IC₅₀)               | [68]       |
|                                                                               | Antioxidant         | XO Inhibition                    | 243 µM (IC₅₀)    | PG 628 µM (IC₅₀) BHA 591 µM (IC₅₀) | [68]       |
| (3R,4R)-3,4-Dihydro-4,6-dihydroxy-3-methyl-1-oxo-1H-isochromene-5-carboxylic acid (34) | Antifungal          | Direct Bioautography Overlay/Cladosporium cladosporioides | 10 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | Nystatin 1µg (Minimum amount required for inhibition of fungi growth on TLC plates) | [17]       |
|                                                                               | Antifungal          | Direct Bioautography Overlay/Cladosporium sphaerospermum | 25 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | Nystatin 1 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | [17]       |
|                                                                               | Acetylcholinesterase inhibitory | TLC-based AChE inhibition | 3 µg (IC) | Galantamine 1µg (IC) | [17]       |
| (3R)-Mellein (35)                                                            | Antifungal          | Agar diffusion/Botrytis cinerea   | 49.2 µg/mL (EC₅₀) | -                                | [53]       |
| 3,4-Dihydro-(3R)-methyl-8-hydroxyisocoumarin                                 | Antifungal          | Direct Bioautography Overlay/Cladosporium cladosporioides | 5 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | Nystatin 1µg (Minimum amount required for inhibition of fungi growth on TLC plates) | [17]       |
| (R)-7-Hydroxymellein (36)                                                    | Antifungal          | Direct Bioautography Overlay/Cladosporium sphaerospermum | 10 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | Nystatin 1 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | [17]       |
|                                                                               | Acetylcholinesterase inhibitory | TLC-based AChE inhibition | 10 µg (IC) | Galantamine 1µg (IC) | [17]       |
Table 2. Cont.

| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|----------------------|-------------------------------|--------------------|------------------|------------|
| (3R,4R)-4,7-Dihydroxymellein (37) | Antifungal | Direct Bioautography Overlay/Cladosporium cladosporioides | 5 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | Nystatin 1 µg (Minimum amount required for inhibition of fungi growth on TLC plates) | [17] |
| (3R)-Methyl-8-hydroxy-6-(hydroxymethyl)-7-methoxydihydroisocoumarin (40) | Antiviral | Spectrophotometer/Anti-TMV | 14.6% GI (20 µM) | Ningnanmycin 28.6% GI (20 µM) | [44] |
| (3R)-Methyl-7,8-dimethoxy-6-(hydroxymethyl)dihydroisocoumarin (41) | Antiviral | Spectrophotometer/Anti-TMV | 21.8% GI (20 µM) | Ningnanmycin 32.8% GI (20 µM) | [112] |
| S-(-)-5-Hydroxy-8-methoxy-4-(1′-hydroxyethyl)-isocoumarin (54) | α-Glucosidase inhibitory | Chromogenic | 537.3 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [62] |
| S-(-)-5,6,8-Trihydroxy-4-(1′-hydroxyethyl)isocoumarin (65) | Antibacterial | Colorimetric broth microdilution/S. aureus (ATCC 27154) | 12.5 µM (MIC<sub>50</sub>) | Ciprofloxacin 0.160 µM (MIC<sub>50</sub>) | [52] |
| | Antibacterial | Colorimetric broth microdilution/B. cereus (ACCC 11077) | 6.25 µM (MIC<sub>50</sub>) | Ciprofloxacin 0.625 µM (MIC<sub>50</sub>) | [52] |
| | Antibacterial | Colorimetric broth microdilution/Vibrio parahemolyticus (ATCC17802) | 6.25 µM (MIC<sub>50</sub>) | Ciprofloxacin 0.160 µM (MIC<sub>50</sub>) | [52] |
| Sescandelin (66) | α-Glucosidase inhibitory | Chromogenic | 417.8 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [62] |
| Compound Name                           | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control          | References |
|----------------------------------------|---------------------|--------------------------------|-------------------|---------------------------|------------|
| Terrecoumarin A (67)                   | Antivirus           | Spectrophotometer/Anti-TMV     | 25.4% GI (20 µM)  | Ningnanmycin 28.6% GI (20 µM) | [44]       |
| Terrecoumarin B (68)                   | Antivirus           | Spectrophotometer/Anti-TMV     | 14.5% GI (20 µM)  | Ningnanmycin 28.6% GI (20 µM) | [44]       |
| Terrecoumarin C (69)                   | Antivirus           | Spectrophotometer/Anti-TMV     | 16.3% GI (20 µM)  | Ningnanmycin 28.6% GI (20 µM) | [44]       |
| LL-Z 1640-7 (72)                       | Antioxidant         | Luciferase                     | 0.87 mM (IC₅₀)    | tBHQ 4.29 mM (IC₅₀)       | [65]       |
| Acremonone G (76)                      | α-Glucosidase inhibitory | Chromogenic                 | 0.37 mM (IC₅₀)    | Acarbose 0.47 mM (IC₅₀)   | [103]      |
| Myrothelactone A (81)                  | α-Glucosidase inhibitory | Chromogenic                 | 0.32 mM (IC₅₀)    | Acarbose 0.47 mM (IC₅₀)   | [103]      |
| 6,8-Dihydroxy-5-methoxy-3-methyl-1H-isochromen-1-one (84) | α-Glucosidase inhibitory | Chromogenic                 | 89.4 µM (IC₅₀)    | Acarbose 958.3 µM (IC₅₀)   | [62]       |
| Myrothelactone C (85)                  | α-Glucosidase inhibitory | Chromogenic                 | 0.036 mM (IC₅₀)   | Acarbose 0.47 mM (IC₅₀)   | [103]      |
| Tubakialactone B (87)                  | α-Glucosidase inhibitory | Chromogenic                 | 0.026 mM (IC₅₀)   | Acarbose 0.47 mM (IC₅₀)   | [103]      |
| 6-Hydroxy-8-methoxy-3,4-dimethylisocoumarin (92) | α-Glucosidase inhibitory | Chromogenic                 | 585.7 µM (IC₅₀)   | Acarbose 958.3 µM (IC₅₀)   | [62]       |
| 3,4-Dimethyl-6,8-dihydroxyisocoumarin (93) | α-Glucosidase inhibitory | Chromogenic                 | 36.4 µM (IC₅₀)    | Acarbose 958.3 µM (IC₅₀)   | [62]       |
| 6-Hydroxy-4-hydroxymethyl-8-methoxy-3-methyl-isocoumarin (94) | α-Glucosidase inhibitory | Chromogenic                 | 302.6 µM (IC₅₀)   | Acarbose 958.3 µM (IC₅₀)   | [62]       |
| Sescandelin B (95)                     | α-Glucosidase inhibitory | Chromogenic                 | 17.2 µM (IC₅₀)    | Acarbose 958.3 µM (IC₅₀)   | [62]       |
| 6-Hydroxy-3-hydroxymethyl-8-methoxyisocoumarin (96) | Antivirus | Spectrophotometer/Anti-TMV | 18.7% GI (20 µM)  | Ningnanmycin 28.6% GI (20 µM) | [44]       |
### Table 2. Cont.

| Compound Name                                                                 | Biological Activity | Assay, Organism, or Cell Line | Biological Results       | Positive Control            | References |
|-------------------------------------------------------------------------------|---------------------|-------------------------------|--------------------------|-----------------------------|------------|
| 4,6-Dihydroxy-3,9-dehydromellein (97)                                        | Antivirus           | Spectrophotometer/Anti-TMV    | 13.8% GI (20 µM)          | Ningnanmycin 28.6% GI (20 µM) | [44]       |
| Botryospyrone A (106)                                                         | Antifungal          | 2-Fold broth dilution         | 112.6 µM (MIC)           | Triadimefon 340 µM (MIC)    | [71]       |
| Botryospyrone B (107)                                                         | Antifungal          | 2-Fold broth dilution         | 105.8 µM (MIC)           | Triadimefon 340 µM (MIC)    | [71]       |
| 4,5,7-Trihydroxy-3-methoxy-3,6-dimethylisochroman-1-one (114)                 | α-Glucosidase       | -                             | IC50 90.4 µM             | Acarbose (IC50 553.7 µM)    | [38]       |
| 3,5-Dimethyl-8-hydroxy-7-methoxy-3,4-dihydroisocoumarin (132)                | Antifungal          | TLC-autobiography             | 50 µg/mL (MIC)           | Nystatin 12.5 µg/mL (MIC)   | [55]       |
|                                                                               |                     | TLC-autobiography             | 50 µg/mL (MIC)           | Nystatin 12.5 µg/mL (MIC)   | [55]       |
|                                                                               | Antibacterial       | Colorimetric broth microdilution/Bacillus subtilis | 25 µg/mL (MIC) | Chloramphenicol 3.13 µg/mL (MIC) | [55]       |
|                                                                               |                     | Colorimetric broth microdilution/Pseudomonas syringae | 100 µg/mL (MIC) | Chloramphenicol 3.13 µg/mL (MIC) | [55]       |
| Periplanetin D (137)                                                          | Antivirus           | Spectrophotometer/Anti-TMV    | 15.5% GI (20 µM)         | Ningnanmycin 28.6% GI (20 µM) | [44]       |
| Pestalactone C (138)                                                          | Antifungal          | Colorimetric broth microdilution/Candida glabrata (ATCC 90030) | 3.49 µg/mL (MIC50) | Amphotericin B 0.25 µg/mL (MIC50) | [22]       |
| (6,8-Dihydroxy-3-methyl-1-oxo-1H-isochromen-4-yl)methyl 3-methylbutanoate (150) | α-Glucosidase       | Chromogenic                   | 140.8 µM (IC50)         | Acarbose 958.3 µM (IC50)    | [62]       |
| Penicimarin F (153)                                                           | Antibacterial       | Colorimetric broth microdilution/S. aureus (ATCC 27154) | 12.5 µM (MIC) | Ciprofloxacin 0.160 µM (MIC) | [52]       |
| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| Penicisimpin A (157) 3-(R)-6,8-Dihydroxy-7-methyl-3-pentylisochroman-1-one | Antibacterial | Well diffusion method/E. coli | 4 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Micrococcus luteus | 8 µg/mL (MIC) | Chloramphenicol 1 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Pseudomonas aeruginosa | 4 µg/mL (MIC) | Chloramphenicol 4 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio alginolyticus | 8 µg/mL (MIC) | Chloramphenicol 0.5 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio harveyi | 4 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio paraheamolyticus | 4 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antifungal | Well diffusion method/Colletotrichum gloeosporioides | 4 µg/mL (MIC) | Amphotericin B 8 µg/mL (MIC) | [58] |
| | Antifungal | Well diffusion method/Phytophthora parasitica var. nicotianae | 6 µg/mL (MIC) | Amphotericin B 16 µg/mL (MIC) | [58] |
| Penicisimpin B (158) 3-(R)-6,8-Dihydroxy-3-pentylisochroman-1-one | Antibacterial | Well diffusion method/Aeromonas hydrophilia | 32 µg/mL (MIC) | Chloramphenicol 32 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/E. coli | 32 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Micrococcus luteus | 64 µg/mL (MIC) | Chloramphenicol 1 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Pseudomonas aeruginosa | 32 µg/mL (MIC) | Chloramphenicol 4 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio alginolyticus | 32 µg/mL (MIC) | Chloramphenicol 0.5 µg/mL (MIC) | [58] |
Table 2. Cont.

| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| Penicisimpin B (158) 3-(R)-6,8-Dihydroxy-3-pentylisochroman-1-one | Antibacterial | Well diffusion method/Vibrio harveyi | 16 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio parahemolyticus | 32 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antifungal | Well diffusion method/Colletotrichum gloeosporioides | 16 µg/mL (MIC) | Amphotericin B 8 µg/mL (MIC) | [58] |
| | Antifungal | Well diffusion method/Phytophthora parasitica var. nicotianae | 32 µg/mL (MIC) | Amphotericin B 16 µg/mL (MIC) | [58] |
| Penicisimpin C (159) 3-(S)-6,8-Dihydroxy-7-methyl-3-(pent-1-enyl)isochroman-1-one | Antibacterial | Well diffusion method/Aeromonas hydrophilia | 16 µg/mL (MIC) | Chloramphenicol 32 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/E. coli | 8 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Micrococcus luteus | 16 µg/mL (MIC) | Chloramphenicol 1 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Pseudomonas aeruginosa | 8 µg/mL (MIC) | Chloramphenicol 4 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio alginolyticus | 16 µg/mL (MIC) | Chloramphenicol 0.5 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio harveyi | 8 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antibacterial | Well diffusion method/Vibrio parahemolyticus | 8 µg/mL (MIC) | Chloramphenicol 2 µg/mL (MIC) | [58] |
| | Antifungal | Well diffusion method/Colletotrichum gloeosporioides | 8 µg/mL (MIC) | Amphotericin B 8 µg/mL (MIC) | [58] |
| Fusarentin 6,7-dimethyl ether (160) | Antioxidant | ORAC | 14.4 µM (IC<sub>50</sub>) | Trolox 1 µM (IC<sub>50</sub>) | [80] |
| Compound Name                          | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------------------------------|---------------------|-------------------------------|--------------------|------------------|------------|
| **Fusarentin 6-methyl ether (161)**   | Antioxidant         | DPPH                          | 16.4 µM (IC$_{50}$) | Ascorbic acid 21.2 µM (IC$_{50}$) | [80]       |
|                                       | Antioxidant         | ORAC                          | 1.4 µM (IC$_{50}$)  | Trolox 1 µM (IC$_{50}$)           | [80]       |
|                                       | Antibacterial       | Agar diffusion/E. coli         | 10 mm (IZD)        | Penicillin 18 mm (IZD)             | [49]       |
|                                       | Antibacterial       | Agar diffusion/Bacillus        | 6 mm (GI)          | Penicillin 14 mm (IZD)             | [49]       |
|                                       | Antifungal          | Agar diffusion/Microbotryum    | 23 mm (IZD)        | Actidione 35 mm (IZD)              | [49]       |
| Monocerin (165)                       | Antialgal           | Agar diffusion/Chlorella fusca | 8 mm (IZD)         | Nystatin 20 mm (IZD)               | [49]       |
|                                       | Antibacterial       | Microbroth dilution/E. coli   | 15.62 µg/mL (MIC)  | -                              | [59]       |
|                                       | Antibacterial       | Pseudomonas aeruginosa         | 15.62 µg/mL (MIC)  | -                              | [59]       |
|                                       | Antibacterial       | S. aureus (ATCC 25923)        | 15.62 µg/mL (MIC)  | -                              | [59]       |
|                                       | Antibacterial       | B. subtilis (ATCC 6633)       | 15.62 µg/mL (MIC)  | -                              | [59]       |
|                                       | Antibacterial       | Salmonella Typhimurium (ATCC 14028) | 31.25 µg/mL (MIC) | -                              | [59]       |
|                                       | Antioxidant         | ORAC                          | 10.8 µM (IC$_{50}$) | Trolox 1 µM (IC$_{50}$)           | [80]       |
|                                       | Antimalarial        | Microculture radioisotope/P. falciparum (K1) | 0.68 µM (IC$_{50}$) | Dihydroartemisinin 0.0004 µM (IC$_{50}$) | [46]       |
| **7-O-Demethylmonocerin (166)**       | Antioxidant         | XXO                           | 52.6 µM (IC$_{50}$) | -                              | [80]       |
|                                       | Antioxidant         | DPPH                          | 23.4 µM (IC$_{50}$) | Ascorbic acid 21.2 µM (IC$_{50}$) | [80]       |
|                                       | Antioxidant         | ORAC                          | 11.5 µM (IC$_{50}$) | Trolox 1 µM (IC$_{50}$)           | [80]       |
|                                       | Antioxidant         | DPPH                          | 38 µM (EC$_{50}$)   | Ascorbic acid 39 µM (EC$_{50}$)   | [64]       |
| **(12R)-12-Hydroxymonocerin (167)**  | Antifungal          | Agar diffusion/Microbotryum    | 7 mm (IZD)         | Actidione 35 mm (IZD)              | [49]       |
| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| (12R)-12-Hydroxymonocerin (167) | Antialgal | Agar diffusion/Chlorella fusca | 6 mm (IZD) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [49] |
| | Antifungal | Colorimetric broth microdilution/F. oxysporum | 20 µg/mL (MIC) | Amphotericin B 0.63 µg/mL (MIC) | [60] |
| (11R)-Hydroxymonocerin (168) | Antimalarial | Microculture radioisotope/P. falciparum (K1) | 7.7 µM (IC₅₀) | Dihydroartemisinin 0.004 µM (IC₅₀) | [46] |
| | Antibacterial | Agar diffusion/E. coli | 8 mm (IZD) | Penicillin 18 mm (IZD) Tetracycline 18 mm (GI) | [49] |
| | Antibacterial | Agar diffusion/B. megaterium | 6 mm (GI) | Penicillin 14 mm (IZD) Tetracycline 18 mm (GI) | [49] |
| | Antifungal | Agar diffusion/Microbotryum violaceum | 9 mm (IZD) | Actidione 35 mm (IZD) | [49] |
| | Antialgal | Agar diffusion/Chlorellafusca | 10 mm (IZD) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [49] |
| Exserolide C (177) | Antifungal | Colorimetric broth microdilution/F. oxysporum | 20 µg/mL (MIC) | Amphotericin B 0.63 µg/mL (MIC) | [60] |
| Alternariol (188) | Antimicrobial | Colorimetric broth microdilution/M. tetragenus | 50 µg/mL (MIC) | Streptomycin 3.125 µg/mL (MIC) Aceomycin 3.125 µg/mL (MIC) Ampicillin 3.125 µg/mL (MIC) | [57] |
| Alternariol 5-O-methyl ether (189) | Antimicrobial | Colorimetric broth microdilution/B. megaterium | 12.5 µg/mL (MIC) | Streptomycin 3.125 µg/mL (MIC) Aceomycin 3.125 µg/mL (MIC) Ampicillin 3.125 µg/mL (MIC) | [57] |
| Cycloepoxylactone (197) | Antibacterial | Agar diffusion/Bacillus megaterium | 5 mm (GI) | Penicillin 14 mm (GI) Tetracycline 18 mm (GI) | [42] |
| | Antifungal | Agar diffusion/Microbotryum violaceum | 10 mm (IZD) | Nystatin 20 mm (IZD) Actidione 50 mm (IZD) | [42] |
Table 2. Cont.

| Compound Name                          | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|----------------------------------------|---------------------|--------------------------------|-------------------|------------------|------------|
| Exserolide F (201)                     | Antibacterial       | Colorimetric broth microdilution/B. subtilis (ATCC 6633) | 20 µg/mL (MIC) | Ampicillin 1.25 µg/mL (MIC) | [60]       |
|                                        | Antibacterial       | S. aureus (CGMCC 1.2465)      | 5 µg/mL (MIC)     | Ampicillin 0.16 µg/mL (MIC) | [60]       |
|                                        | Antibacterial       | S. pneumoniae (CGMCC 1.1692)  | 10 µg/mL (MIC)    | Ampicillin 10 µg/mL (MIC) | [60]       |
|                                        | Antibacterial       | E. coli (CGMCC 1.2340)        | 20 µg/mL (MIC)    | Gentamicin 2.5 µg/mL (MIC) | [60]       |
| Isocitreoisocoumarinol (202)           | Antioxidant         | Luciferase                     | 0.98 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| (+) Citreoisocoumarin (203)            | Antioxidant         | Luciferase                     | 1.03 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| (+)-6-Methylcitreoisocoumarin (204)    | α-Glucosidase inhibitory | Chromogenic                   | 38% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31]       |
|                                        | Antioxidant         | Luciferase                     | 0.98 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Citreoisocoumarinol (205)              | Antioxidant         | Luciferase                     | 0.91 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Muoricoscoumarin A (207)               | Antioxidant         | Luciferase                     | 0.88 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Muoricoscoumarin B (208)               | Antioxidant         | Luciferase                     | 1.03 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Peyroisocoumarin A (209)               | Antioxidant         | Luciferase                     | 1.93 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Peyroisocoumarin B (210)               | Antioxidant         | Luciferase                     | 2.95 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Peyroisocoumarin C (211)               | Antioxidant         | Luciferase                     | 1.46 mM (IC<sub>50</sub>) | tBHQ 4.29 mM (IC<sub>50</sub>) | [65]       |
| Aspergillumarin A (212)                | α-Glucosidase inhibitory | Chromogenic                   | 38.1 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [62]       |
|                                        | Antibacterial       | Colorimetric broth microdilution/S. albus (ATCC 8799) | 12.5 µM (MIC<sub>50</sub>) | Ciprofloxacin 0.312 µM (MIC<sub>50</sub>) | [52]       |
| Aspergillumarin B (213)                | α-Glucosidase inhibitory | Chromogenic                   | 193.1 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [62]       |
|                                        | Antibacterial       | Colorimetric broth microdilution/S. albus (ATCC 8799) | 12.5 µM (MIC<sub>50</sub>) | Ciprofloxacin 0.312 µM (MIC<sub>50</sub>) | [52]       |
| Compound Name                                           | Biological Activity                | Assay, Organism, or Cell Line | Biological Results | Positive Control          | References |
|----------------------------------------------------------|------------------------------------|--------------------------------|--------------------|---------------------------|------------|
| Penicimarin B (214)                                      | α-Glucosidase inhibitory           | Chromogenic                    | 431.4 μM (IC<sub>50</sub>) | Acarbose 958.3 μM (IC<sub>50</sub>) | [62]       |
| Penicimarin C (215)                                      | α-Glucosidase inhibitory           | Chromogenic                    | 266.3 μM (IC<sub>50</sub>) | Acarbose 958.3 μM (IC<sub>50</sub>) | [62]       |
| (R)-3-(R)-4,5-Dihydroxypentyl)-8-hydroxyisochroman-1-one (216) | α-Glucosidase inhibitory           | Chromogenic                    | 162.5 μM (IC<sub>50</sub>) | Acarbose 958.3 μM (IC<sub>50</sub>) | [62]       |
| 5,6-Dihydroxy-3-(4-hydroxypentyl)isochroman-1-one (217)  | α-Glucosidase inhibitory           | Chromogenic                    | 142.1 μM (IC<sub>50</sub>) | Acarbose 958.3 μM (IC<sub>50</sub>) | [62]       |
| Anti-inflammatory                                        | Colourmetric/NO                    |                                | 67.2 μM (MIC<sub>50</sub>) | Indomethacin 37.5 μM (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Colorimetric broth microdilution/ *Staphylococcus aureus* |                                | 25 μg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 μg/mL (MIC<sub>50</sub>) Gentamicin 0.1 μg/mL (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Colorimetric broth microdilution/ *B. subtilis* |                                | 25 μg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 μg/mL (MIC<sub>50</sub>) Gentamicin 0.1 μg/mL (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Colorimetric broth microdilution/ *E. coli* |                                | 50 μg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 μg/mL (MIC<sub>50</sub>) Gentamicin 0.1 μg/mL (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Colorimetric broth microdilution/ *Klebsiella pneumoniae* |                                | 50 μg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 μg/mL (MIC<sub>50</sub>) Gentamicin 0.1 μg/mL (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Colorimetric broth microdilution/ *Actinobacter calcoaceticus* |                                | 50 μg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 μg/mL (MIC<sub>50</sub>) Gentamicin 0.1 μg/mL (MIC<sub>50</sub>) | [37]       |
| Antibacterial                                            | Broth dilution/ *Colletotrichium musae* |                                | 150 μg/mL (IC<sub>50</sub>) | Carbendazim 6.25 μg/mL (IC<sub>50</sub>) | [66]       |
| Antifungal                                               | Broth dilution/ *Rhizoctonia solani* |                                | 150 μg/mL (IC<sub>50</sub>) | Carbendazim 6.25 μg/mL (IC<sub>50</sub>) | [66]       |
| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|----------------------|-------------------------------|--------------------|------------------|------------|
| **Desmethyldichlorodiaportin (221)** | Anti-inflammatory | Colourmetric/NO | 33.6 µM (MIC<sub>50</sub>) | Indomethacin 37.5 µM (MIC<sub>50</sub>) | [37] |
|      | Antibacterial | Colorimetric broth microdilution/S. aureus | 25 µg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 µg/mL (MIC<sub>50</sub>) | [37] |
|      | Antibacterial | Colorimetric broth microdilution/B. subtilis | 25 µg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 µg/mL (MIC<sub>50</sub>) | [37] |
|      | Antibacterial | Colorimetric broth microdilution/E. coli | 25 µg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 µg/mL (MIC<sub>50</sub>) | [37] |
|      | Antibacterial | Colorimetric broth microdilution/Klebsiella pneumoniae | 25 µg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 µg/mL (MIC<sub>50</sub>) | [37] |
|      | Antibacterial | Colorimetric broth microdilution/Acinetobacter calcoaceticus | 50 µg/mL (MIC<sub>50</sub>) | Ciprofloxacin 0.25 µg/mL (MIC<sub>50</sub>) | [37] |
| **Peniisocoumarin D (222)** | α-Glucosidase inhibitory | Chromogenic | 41% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31] |
| **Peniisocoumarin E (223)** | α-Glucosidase inhibitory | Chromogenic | 158.4 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [31] |
| **Peniisocoumarin F (224)** | α-Glucosidase inhibitory | Chromogenic | 110.3 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [31] |
| **Peniisocoumarin G (225)** | α-Glucosidase inhibitory | Chromogenic | 40.5 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [31] |
| **Peniisocoumarin H (226)** | α-Glucosidase inhibitory | Chromogenic | 43% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31] |
| **Peniisocoumarin I (227)** | α-Glucosidase inhibitory | Chromogenic | 78.1 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [31] |
| **Peniisocoumarin J (228)** | α-Glucosidase inhibitory | Chromogenic | 45.1 µM (IC<sub>50</sub>) | Acarbose 958.3 µM (IC<sub>50</sub>) | [31] |
Table 2. Cont.

| Compound Name | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|---------------|---------------------|-------------------------------|--------------------|------------------|------------|
| 3-[(R)-3,3-Dichloro-2-hydroxypropyl]-8-hydroxy-6-methoxy-1H-isochromen-1-one (229) | α-Glucosidase inhibitory | Chromogenic | 102.4 µM (IC₅₀) | Acarbose 958.3 µM (IC₅₀) | [31] |
| (+)-Diaporthin (230) | α-Glucosidase inhibitory | Chromogenic | 33% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31] |
| Diaportinol (231) | Antioxidant | Luciferase | 0.85 mM (IC₅₀) | tBHQ 4.29 mM (IC₅₀) | [65] |
| (+)-(10R)-7-Hydroxy-3-(2-hydroxy-propyl)-5,6-dimethylisochromen-1-one (232) | Antibacterial | Colorimetric broth microdilution/B. subtilis (ATCC 6633) | 19.2 µg/mL (MIC₈₀) | Penicillin 0.9 µg/mL (MIC₈₀) | [63] |
| | Antifungal | Colorimetric broth microdilution/Trichophyton rubrum (ATCC 28189) | 32 µg/mL (MIC₈₀) | Fluconazole 1 µg/mL (MIC₈₀) | [63] |
| Peyroisocoumarin D (233) | Antioxidant | Luciferase | 2.28 mM (IC₅₀) | tBHQ 4.29 mM (IC₅₀) | [65] |
| Orthosporin (234) | Antioxidant | Luciferase | 1.58 mM (IC₅₀) | tBHQ 4.29 mM (IC₅₀) | [65] |
| Versicoumarin A (251) | Anti-TMV | Half-leaf method | 28.6% (Inhibition rate) | Ningnanmycin 31.5% (Inhibition rate) | [93] |
| Peniisocoumarin C (258) | α-Glucosidase inhibitory | Chromogenic | 95% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31] |
| Asperisocoumarin A (261) | Antioxidant | DPPH | 125 µM (EC₅₀) | Ascorbic acid 35 µM (EC₅₀) | [76] |
| Asperisocoumarin B (262) | α-Glucosidase inhibitory | Chromogenic | 87.8 µM (IC₅₀) | Acarbose 628.3 µM (IC₅₀) | [76] |
| Asperisocoumarin C (263) | Antioxidant | DPPH | 138 µM (EC₅₀) | Ascorbic acid 35 µM (EC₅₀) | [76] |
| Asperisocoumarin E (265) | α-Glucosidase inhibitory | Chromogenic | 52.3 µM (IC₅₀) | Acarbose 628.3 µM (IC₅₀) | [76] |
| Asperisocoumarin F (266) | α-Glucosidase inhibitory | Chromogenic | 95.6 µM (IC₅₀) | Acarbose 628.3 µM (IC₅₀) | [76] |
| Peniiisocoumarin A (267) | α-Glucosidase inhibitory | Chromogenic | 18% Inhibition (200 µM) | Acarbose 19% Inhibition (200 µM) | [31] |
| Compound Name               | Biological Activity | Assay, Organism, or Cell Line | Biological Results | Positive Control | References |
|----------------------------|---------------------|-------------------------------|--------------------|------------------|------------|
| Peniisocoumarin B (268)    | α-Glucosidase inhibitory | Chromogenic                  | 23% Inhibition (200 μM) | Acarbose 19% Inhibition (200 μM) | [31]      |
| Demethylcitreoviranol (286)| Antioxidant         | Luciferase                   | 1.06 mM (IC₅₀)         | tBHQ 4.29 mM (IC₅₀)      | [65]      |
| Citreoviranol (287)        | Antioxidant         | Luciferase                   | 1.44 mM (IC₅₀)         | tBHQ 4.29 mM (IC₅₀)       | [65]      |
| Dichlorodiaportinolide (290)| Antifungal         | Broth dilution/Colletotrichum musae | 25 μg/mL (IC₅₀)         | Carbendazim 6.25 μg/mL (IC₅₀) | [66]      |
|                            | Antifungal         | Broth dilution/Rhizoctonia solani | 6.25 μg/mL (IC₅₀)  | Carbendazim 6.25 μg/mL (IC₅₀) | [66]      |
| Dichlorodiaportintone (291)| Anti-inflammatory  | Colourmetric/NO              | 41.5 μM (MIC₅₀)        | Indomethacin 37.5 μM (MIC₅₀) | [37]      |
|                            | Antibacterial      | Colorimetric broth microdilution/S. aureus | 50 μg/mL (MIC₅₀)        | Ciprofloxacin 0.25 μg/mL (MIC₅₀) | [37]      |
|                            | Antibacterial      | Colorimetric broth microdilution/E. coli | 50 μg/mL (MIC₅₀)        | Ciprofloxacin 0.25 μg/mL (MIC₅₀) | [37]      |
|                            | Antibacterial      | Colorimetric broth microdilution/Klebsiella pneumoniae | 50 μg/mL (MIC₅₀)        | Ciprofloxacin 0.25 μg/mL (MIC₅₀) | [37]      |
| Desmethyldichlorodiaportintone (292) | Anti-inflammatory | Colourmetric/NO              | 15.8 μM (MIC₅₀)        | Indomethacin 37.5 μM (MIC₅₀) | [37]      |
| Botryoisocoumarin A (293)  | Anti-inflammatory  | Colourmetric/COX-2           | 6.51 μM (IC₅₀)         | -                | [36]      |
Table 3. Cytotoxic activity of the most active fungal isocoumarins.

| Compound Name | Assay, Cell Line       | Cytotoxicity Results | Positive Control             | References |
|---------------|------------------------|----------------------|------------------------------|------------|
| Penicisimpin A (157) | Brine shrimp (Artemia salina) lethality | 7.7 µg/mL (LD_{50}) | Colchicine 16.5 µg/mL (LD_{50}) | [58] |
| Penicisimpin B (158) | 3-(R)-6,8-Dihydroxy-3-pentylisochroman-1-one | 36.4 µg/mL (LD_{50}) | Colchicine 16.5 µg/mL (LD_{50}) | [58] |
| Penicisimpin C (159) | 3-(S)-6,8-Dihydroxy-7-methyl-3-(pent-1-enyl)isochroman-1-one | 18.6 µg/mL (LD_{50}) | Colchicine 16.5 µg/mL (LD_{50}) | [58] |
| 7-O-Demethylmonocerin (166) | MTT/HepG2 | 23.7 µM (IC_{50}) | Etoposide 15.8 µM (IC_{50}) | [80] |
| Aspergisocoumarin A (274) | 43.70 µM (IC_{50}) | Epirubicin 0.32 µM (IC_{50}) | [73] |
| Dichlorodiaportinol A (289) | 39.6 µg/mL (EC_{50}) | Epirubicin 5.2 µg/mL (IC_{50}) | [79] |
| (+) Citreoisocoumarin (203) | MTT/L5178Y | 99.5% GI (10 µg/mL) | 0.1% EGME/DMSO | [40] |
| Desmethyldiaportinol (219) | 7.3 µg/mL (IC_{50}) | Kahalalide F 6.4 µg/mL (EC_{50}) | [40] |
| Desmethyldichlorodiaportin (221) | 41.4% GI (10 µg/mL) | 0.1% EGME/DMSO | [40] |
| 6,6'-Dinor-bipenicilisorin (259) | 13% GI (10 µg/mL) | Gerfelin 85% GI (10 µg/mL) | [81] |
| 6,6',9'-Trinor-bipenicilisorin (260) | 33% GI (10 µg/mL) | Gerfelin 85% GI (10 µg/mL) | [81] |
| Versicoumarin A (251) | 3.8 µM (IC_{50}) | Taxol 0.1 µM (IC_{50}) | [93] |
| Versicoumarin D (252) | 8.0 µM (IC_{50}) | Taxol | [89] |
| Dichlorodiaportinol A (289) | 17.8 µg/mL (EC_{50}) | Epirubicin 5.3 µg/mL (IC_{50}) | [79] |
| Penisocoumarin G (225) | 20.1 µM (IC_{50}) | Oleanolic acid 22.1 µM (IC_{50}) | [31] |
| Versicoumarin A (251) | 4.0 µM (IC_{50}) | Taxol 0.02 µM (IC_{50}) | [93] |
| Versicoumarin D (252) | 5.8 µM (IC_{50}) | Taxol | [89] |
| Aspergisocoumarin A (274) | 5.08 µM (IC_{50}) | Epirubicin 0.26 µM (IC_{50}) | [73] |
| Aspergisocoumarin B (275) | 4.98 µM (IC_{50}) | Epirubicin 0.26 µM (IC_{50}) | [73] |
| Aspergisocoumarin A (274) | 11.34 µM (IC_{50}) | Epirubicin 0.13 µM (IC_{50}) | [73] |
| Aspergisocoumarin B (275) | 21.40 µM (IC_{50}) | Epirubicin 0.13 µM (IC_{50}) | [73] |
| Aspergisocoumarin A (274) | 21.53 µM (IC_{50}) | Epirubicin 0.12 µM (IC_{50}) | [73] |
| Isocoumarindole A (296) | CCK colorimetric/MIA-PACA-2 | 1.63 µM (IC_{50}) | Gemcitabine 1.02 µM (IC_{50}) | [29] |
| | CCK colorimetric/ASPC-1 | 5.53 µM (IC_{50}) | Gemcitabine 20.10 µM (IC_{50}) | [29] |
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Abbreviations

1D: One Dimensional; 2D: Two Dimensional; A2780: Human Ovarian Cancer Cell Line; A375-S2: Human Malignant Melanoma Cell Line; A375-CS: Human Malignant Melanoma IL-1 Insensitive; A549: Human Lung Carcinoma Cell Line; AChE: Acetylcholinesterase; AGS: Gastric Adenocarcinoma Cell Line; ARE: Antioxidant Response Element; ARK5: NUAK Family SNF1-Like Kinase 1; ASPC-1: Pancreatic Adenocarcinoma Cell Line; Aurora A: Aurora A Kinase; Aurora B: Aurora B Kinase; BFHEnz: Bifunctional Hybrid Enzyme; BGC823: Kind of Vascular Endothelial Growth Factor A; VEGF-R3: Vascular Endothelial Growth Factor 3; VLC: Vacuum Liquid Chromatography; XO: Xanthine Oxidase; XXO: Xanthine Oxidase.

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