Alkaloids are a secondary metabolite, which are extracted from a wide – array of organisms include Bacteria, Fungi, Plants and Animals. Here in present review mainly focused on the alkaloids derived from endophytic fungi and non – endophytic fungi. Fungi have provided a great source of spirit for novel drug compounds as fungi derived alkaloids have done major boon to human health and well - being. In the present review listed 35 different group of alkaloids from endophytes. In which 12 different alkaloids are kept under derivatives of Indole group, 4 different alkaloids are kept under Quinoline group, 4 different alkaloids kept under amines and amide group, from non-endophytic alkaloid 27 different group of alkaloids are reported. In which 9 different type of alkaloid are mentioned under indole group of alkaloids, 4 alkaloids are reported under diketopiperazine alkaloids, 4 different alkaloids are mentioned under ergot group of alkaloids, 3 alkaloids under prenylated indole alkaloids, 3 alkaloids are mentioned under pyrrolizidine, imidazole, piperidine, tropine, purine, pyrrolizidine, imidazole, quinolizidine, isoquinoline, and pyrrolidine alkaloids. Many scientists have propositioned distinct classification for alkaloids. One of the famous classifications that fractionate entire alkaloid compounds into 3 categories.

1. TRUE ALKALOIDS: these are the compounds which are acquired from an amino acid and have a heterocyclic ring with nitrogen. Example: Nicotine etc.
2. PROTO ALKALOIDS: these are the compound, which are obtained from an amino acid and possess nitrogen atom but it is not a segment of the heterocyclic ring. Example: Adrenaline etcetera.
3. PSEUDO ALKALOIDS: these are the compounds that do not derived from amino acids. Example: Caffeine etc.

Endophytic fungi are fungi that deaden indiscrete or proportion of their lifecycle colonizing interior intra cellulary inside tissues of the plants, generally do not cause any obvious symptoms of disease. These fungi can cause numerous secondary metabolites, some of these are alkaloids. The characterization of endophytic fungi is stressed as a significant position of causing for drug. Endophytic fungi generally attain nutrition or food and shelter from the host plant, reciprocated; they favor jeopardous amplified congruence to the host plants by generating some functional metabolites. Endophytic fungi inhare plant tissues without sabotaging or generating compounds that that attributable an infection to the host cell. Their coexistence means that the endophytes generate the similar or same substances to those arising from the plant. Endophytic fungi have been of immense
interest from the last 20 years as potential generator of biologically active resource. They are a wealthy notch of functional secondary metabolites that contain flavonoids, terpenoids, steroids, phenol, phenylpropanoid, quinines, indole derivatives, amines, alkaloids, amides, pyrrolizidines, aliphatic isocoumarin derivatives.

Endophytes were first noted by the German Botanist Johann Henrich Friedrich Link in 1809. They were conception to be plant parasitic fungi and they were conception to be plant parasitic fungi and they were subsequent named as ‘Microzymas’ by French scientist Antonie. Bechamp. Endophytes may be imparted either direct from parent to progeny or among individuals. Endophytes which transmitted from parent to offspring are ordinarily literalized clonal and impart through fungal hyphae penetrating the embryo within the host’s seeds, while reproduction of the fungi via asexual conidia or through sexual spore initiatives to horizontal transmission, where endophytes may propagate between plants in a population or community. Endophytes and plants apparently involve in mutualism, with endophytes, firstly aiding in the health and abidence of the host plant with subjects like pathogens and disease, water and heat stresses, nutrient accessibility and sillabub soil quality etc. In consideration, the endophytes experience carbon for energy from the plant host. Plant microbe correlations are not rigorously mutualistic as endophytic fungi can efficiently bechance pathogens or saprotrophs generally when the plant is accentuating. Endophytes may bechance operative and reproduce beneath particular environmental situations or when their host plants are pressurized or start to aging, desperately localizing the quantity of carbon provided to the endophyte.

### Endophytic Fungal Alkaloids

In this review, we tried to provide an overview of the alkaloids that are derived from the different endophytic and non-endophytic fungi and potential against different diseases. And here we have mentioned 35 different groups of alkaloids. 12 different alkaloids are mentioned under derivatives of Indole group, 4 different alkaloids from Quinoline group, 4 different alkaloids from amines and amide group, 3 type of alkaloids from pyridone group, 2 different alkaloids under pyridines alkald, 2 alkaloids from quinazolines, 2 different alkaloids from indolizidine alkaloid group, 2 different alkaloids from spiroheterocyclic alkaloid group, 2 different alkaloids from chromone alkaloid group, 2 different alkaloids from steroidal alkaloid group, 2 alkaloids are mentioned under indole diketopiperazine alkaloids, 2 alkaloids from diketopiperazine alkaloid, 2 alkaloids from pyrrole group, 2 alkaloids from isoquinoline group, 2 alkaloid from indole – terpene alkaloid, 1 alkaloid from azaphilone alkaloid, 1 alkaloid from cinchona alkaloid group, 1 alkaloid from ergot group, 1 alkaloid from indole diterpene alkaloid, 1 alkaloid from loline group, 1 alkaloid from angularly prenylated indole alkaloid, 1 alkaloid from macfortine alkaloid, 1 alkaloid from benzophenanthridine alkaloid, 1 alkaloid from antileishmanial diketopiperazine alkaloid, 1 alkaloid from spiroquinazoline alkaloid, 1 alkaloid from flavipin derived alkaloid, 1 alkaloid from dioxopiperazine alkaloid, 1 alkaloid from dibenz-o-pyrene alkaloid, 1 alkaloid from prenylated indole alkaloids, 1 alkaloid from polyketide isoquinoline alkaloid, 1 alkaloid from dimeric pyrrolidine alkaloid, 1 alkaloid from sesquiterpene alkaloid, 1 alkaloid from quinzolinone alkaloid, 1 alkaloid from epipolythiodioxopiperazine group and 1 alkaloid from oxepine containing diketopiperazine type alkaloid (Table 1).

Camptothecine is a quinoline alkaloid, was produced by Fusarium solani, Formitopsis sp. Alternaria alternata and Phomopsis sp., which has great activity in the clinical use against ovarian small lung and refractory ovarian cancers and also acts as a chemotherapeutic agent in the treatment of leukemia.

Penicillium sp., have the ability to produce alkaloids such as Shearinines A, D – K, Paspalitrem A, Paspaline, Penicidones A - C, Melaeagrine, Chrysogine, Chrysogennamide A, Penioxamide A, Glandicoline B, Cerevisoler, Trihistatin, Peninsulfuranols A - F, Spirotrypstatin F, most of these alkaloids exhibited antimicrobial activity and anti-malignant activities on human cancer cell lines.

Chaetomium sp., produces alkaloids such as Chaetoglobosin B – D, F, G, Chaetominine, Swainsonine, Chaetofusin A – B, Chaetoseminudin F – G, which exhibited anticancer activity on breast cancer cell lines and antimicrobial activity.

Aspergillus fumigatus sp., produces alkaloids such as Pseurotin A, Asperfumoid, Pyripyropene A and E, Chaetominine, Tryptoquivaline J exhibited anti-inflammatory, immunosuppressive activities and Asperfungoid alkaloid showed Antifungal activity particularly against candida albicans.

Fusarium oxysporum produces Vinblastine and Vincristine which are used as an anticancer agent, and alkaloid Rohitukine used in chronic lymphocytic leukemia cancer treatment respectively.
### Table-1: Alkaloids from Endophytic fungi

| S. No | Class | Name of Alkaloid | fungal isolate | Host | Function | Reference |
|-------|-------|------------------|----------------|------|----------|-----------|
| 1     | Amines and amides | Phomenoamide | Phomopsis sp. PUS-D15 | Leaves of Garcinia dulcis Kuiz | Antibacterial | Zhang et al., 2012 |
| 2     | Amines and amides | p-aminoacetophenonic | Streptomyces sp. | Mangrove Aegiceras cornulatum | Pharmacological activities | Zhang et al., 2012 |
| 3     | Amines and amides | 7- amino-4- methylcoumarin | Xylaria sp. | Ginkgo biloba L. | Antibacterial and Antifungal activities | Zhang et al., 2012 |
| 4     | Amines and amides | Ergot | Clavicepspurpurea | Rye, wheat and Millets grains | pharmaceutical uses | Zhang et al., 2012 |
| 5     | Azaphilone alkaloids | Chaetofusins A and B | Chaetomium fusiforme | Liverwort Scapania verrucose | Antifungal activity | Kuiklev et al., 2016 |
| 6     | Benzophenanthridine alkaloid | Sanguinarine | Fusarium proliferatum BLH51 | Mauleaya cordata | Antibacterial, Anthelmintic and Anti-inflammatory | Wang et al., 2013 |
| 7     | Chromone alkaloid | Rohitukine, flavopiridol | Fusarium oxysporum, Fusarium solani Gibberella fujikuroi | Amoora rohituka, Dysoxylum bintectariferum | Chronic lymphocytic Leukemia cancer treatment, Anti – inflammatory, antiancer and immunotherapy. | Kumara P. M et al., 2014 |
| 8     | Cinchona alkaloids | Quinine, Quinidine, Cinchonidine, Cinchonine | Diaportha sp. | Cinchona ledgeriana | Antimalarial | Maehara et al., 2012 |
| 9     | Dibenzo – α – pyrone alkaloid | Rhizovagine A | Rhizopycnis vagum Nita22 | Nicotiana tabacum | Acetylcholinesterase inhibitory activity | Wang et al., 2020 |
| 10    | Diketopiperazine alkaloid | SS-hydroxyNorvaline-S-Ile | Penicillium sp. GD6 | Chinese Mangrove Bruguiera gymnorrhiza | Antibacterial | Jiang. C. S et al., 2018 |
| 11    | Diketopiperazine alkaloid | Tryhistatin | Penicillium sp. HS-3 | stems of Huperzia serrata | Antimicrobial activity | Shan et al., 2010 |
| 12    | Diketopiperazine alkaloids | piperazine-2,5-dione-1 and 2 | Trichosporum sp. | Seeds of Trigonella foenum-graecum (fabaceae) | Antileishmanial activities | Metwaly et al., 2015 |
| 13    | Dimeric pyrrolidine alkaloid | Collacyclumines A-D | Colletotrichum salsoae SC5041021 | Kandelia candel | Antimicrobial activity | Lin et al., 2020 |
| 14    | Dioxopiperazine alkaloids | Dehydrovariecolorin L and dehydroechimulin | Eurotium rubrum | Stem of mangrove plant Hibiscus tilaeus | Cytotoxic effect | Li et al., 2008 |
| 15    | Epipolythiodioxopiperazine (ETP) | Penisulfuranols A - F | Penicillium janthinellum HDN13-309 | Root of Sonneratia caseolaris | Cytotoxic activities | Zhu et al., 2016 |
| 16    | Ergot alkaloids | Fumigaclavine C and Pseudoert A | Aspergillus sp. EJC08 | Bauhinia guianensis medicinal plant | Antibacterial | Pinheiro et al., 2013 |
| 17    | Flavipirin – derived alkaloids | Azacoccones F-H | Epicoccum nigrum MK214079 | Leaves of Salix sp. | Antibacterial activity | Harwoko et al., 2020 |
| 18    | Indole – diterpene alkaloids | Lolitrem B | Epichole sp | Rye grass | Toxicity in insects | Philippe, 2016 |
| 19    | Indole alkaloid | Glandicoline B, | Penicillium sp | Roots of Mauritia flexuosa | Antimicrobial activity | Koolen et al., 2012 |
| 20    | Indole alkaloid | Piperine | Periconia sp. | Piper longum | Antituberculosis activity | Verma et al., 2011 |
| 21    | Indole alkaloids | Vincamine | Geomyces sp | Nerium indicum | Nootropic drugs - Cerebral insufficiencies treatment | Na et al., 2016 |
| 22    | Indole alkaloids | Vinblastine and vincristine | Fusarium solani, Fusarium oxysporum | Catharanthus roseus | Anticancer agents | Kumar et al., 2013 |
| 23    | Indole alkaloids | Fumitremorgin B and C | Alternaria sp. FL25 | Ficus carica | Anticancerous activity | Feng et al., 2010 |
| 24    | Indole alkaloids | Cristatumins A-D | Eurotium cristatum EN-220 | Marine alga Sargassum thanbergii | Antibacterial activity Cristatumins D showed average lethal activity | Du et al., 2012 |
| 25 | Indole alkaloids | Chotoeminudin F and G | Chaetomium sp. SYP-F7930 | Panax notoginseng | Antibacterial activity | Peng et al., 2019 |
| 26 | Indole derivatives | Chaetoglobosin B-D, E-G | Chaetomium clatum | Isolated from soil | Anticancer agents | Zhang et al., 2012 |
| 27 | Indole derivatives | Shearinines A, D – K, Paspalitrema A and paspaline | Penicillium sp. | Aegiceras corniculatum | Showed blocking activity on large conductance calcium – activated potassium channels in vitro | Zhang et al., 2012 |
| 28 | Indole diketopiperazine alkaloids | Isovariecolorin I | Eurotium cristatum EN-220 | Marine alga Sargassum thunbe | Exhibited antioxidative activities and showed lethal activity against brine shrimp | Du et al., 2017 |
| 29 | Indole diketopiperazine alkaloids | Spirotryprostatin F | Penicillium brefeldianum | Solid cultures | Showed cytotoxic effects toward HepG2 and MDA – MB – 231 cells with inhibition concentration (IC50) values of 14.1µmol/L and 35.9µmol/L | Gao et al., 2017 |
| 30 | Indolizidine alkaloids | Swainsonine | Chaetomium sp. | Swainsona canescens | An α-mannosidase and mannosidase ii | Grum et al., 2013 |
| 31 | Indolizidine alkaloids | Swainsonine | Alternaria oxtypotis | Astragalus and oxtypotis genera | As a Selective inhibitor of both lysosomal acid and cytosolic α – mannosidase ii | Song et al., 2019, Cook et al., 2014, |
| 32 | Indolosquiterpenoid alkaloids | Mycoleptodiscins A and B | Mycoleptodiscus sp. | Desmodes incompressibilis in Panama | Anticancer agent | Ortega et al., 2013 |
| 33 | Isoquinoline alkaloid | 5-hydroxy-8-methoxy-4-phenylisoquinolin – 1 (2H)–one, 3-O-methylviridicatin and viridicatol | Penicillium sp. R22 | Nerium indicum | All three showed antifungal activities and viridicatol showed antibacterial activity toward staphylococcus aureus with minimum inhibitory concentration (MIC) value of 15.6µg/mL | Ma et al., 2017 |
| 34 | Loline alkaloids | Amino pyrrolizidines | Neotyphodium uncinatum | Meadow fescue grass | Defense mechanism toward insect herbivores | Blankenship et al., 2001 |
| 35 | Macfornine group of alkaloids | Chrysogenamid A | Penicillium chrysogenum | Cistanche deserticola Y.C. Ma | Showed a neurote protection effect toward oxidative stress – induced cell death in SH-SYSY cells | Lin et al., 2008 |
| 36 | Meleagrine alkaloid | Meleagrine and chrysochine | Penicillium sp. | Annona squamosa L. | Meleagrine alkaloid exhibited inhibitory activities toward leukemia | Yunianto et al., 2014 |
| 37 | Mycoleptodiscin alkaloids | Mycoleptodiscin B | Mycoleptodiscus sp. | Calamus thwaitesii Becc | Antimicrobial activity | Dissanayake, et al., 2016 |
| 38 | Oxepine containing diketopiperazine type alkaloids | Varioioids A and B | Paecilomyces variotii EN – 291 | Algal derived | Displayed potent activity toward the plant pathogenic fungus Fusarium graminearum | Zhang et al., 2015 |
| 39 | Polyketide isoquinoline alkaloid | Fusarinine | Fusarium sp. LN12 | Melia azedarach | Antibacterial activity | Yang et al., 2012 |
| 40 | Prenylated indole alkaloid | Penoxamide A and 18-hydroxydecaturin B | Penicillium oxalicium EN – 201 | From the Leaves of Rhizophora stylosa | Exhibited potent brine shrimp lethality with lethal dose (LD50) values of 5.6 and 2.3µM respectively | Zhang et al., 2015 |
| 41 | Prenylated indole alkaloids | Aomoenamide C and Sclerotiamide B | Fusarium sambucinum | Nicotiana tabacum | Insecticidal activities | Zhang et al., 2019 |
| 42 | Protoberberine alkaloid | Palmitine 7 – N – oxide | Coelomycetes AFKR – 3 | Young stems of yellow moon seed plant, Archangelisia flava (L.) Merr. | Antimicrobial activity toward pathogenic bacteria and fungi | Agusta et al., 2014 |
| 43 | Pyridine alkaloid | Pyrpyropene A and E, 1,11-dideacetyl-pyrpyropene A, Chaetominine, Tryptoquivaline J, Fumitremorgen C, 1-acetyl-β-caroline and nicotinic acid | Aspergillus fumigatus HQD24 | Chinese mangrove plant Rhizophora mucronate | They exhibited immunsuppressive and cytotoxic activities | Zou et al., 2021 |
|---|---|---|---|---|---|---|
| 44 | Pyridines | Penicidones A -C | Penicillium sp. | Stem of Quercus variabilis | Anticancer agent Showed moderate cytotoxicity on human cancer cell lines | Zhang et al., 2012 |
| 45 | Pyridone alkaloid | Campyridones A-D | Campylocarpon sp. HDN13-307 | From the Roots of mangrove plant, Sonneratia caseolaris | Exhibited cytotoxic activity toward P388 cells | Zha et al., 2016 |
| 46 | Pyridone alkaloids | Fusapyridons A and B | Fusarium sp. YG - 45 | Maackia chinensis | Displayed antimicrobial activity toward Pseudomonas aeruginosa and staphylococcus aureus | Tsuchinari et al., 2007 |
| 47 | Pyridone alkaloids | Tolpyridone A | Tolypocladium cylindrosporum (endolichen fungus) | Lethariella zahlbruckneri | Cytotoxic effects on human tumor cells | Li et al., 2015 |
| 48 | Pyrrole alkaloid | N-[4-(2-formyl-5-hydroxymethyl-pyrrol-1-yl)-butyl]-acetamide | Fusarium incarnatum (HKI00504) | Aegiceras corniculatum | Cytotoxic activities | Li et al., 2008 |
| 49 | Pyrrolidones alkaloids | Phomapyrrolidones A-C | Phoma sp. | Saurauia scaberrinae | Showed poor antitubercular activity at subcytotoxic concentrations | Wijeratne et al., 2013 |
| 50 | Quinazoline alkaloid | (1R,4R)-1,4-(2,3)-indolmethane-1-methyl-2,4-dihydropyrrazine-2,1-b]-quinazoline-3,6-dione | Penicillium vinaceum | Crocus sativus | Antifungal agent | Zheng et al., 2011 |
| 51 | Quinazolines | Chaetominine | Chaetomium sp. | Adenophora axilliflora leaves | Anticancer agent Showed high cytotoxicity toward human leukemia K562 | Zhang et al., 2012 |
| 52 | Quinazolinone alkaloids | Aniquinazolines A-D | Aspergillus nidulans | Rhizophora stylosa | Showed antibacterial and cytotoxic activity | An, et al., 2013 |
| 53 | Quinoline | Camptothecine (CPT) | Fusarium solani, Fomitopsis sp., Alternaria alternata and Phomopsis sp. | Nethapodytes fortilae(grass), andMiquelia dentata Beld | As a chemotherapeutic agent in the treatment of leukemia and clinical use toward ovarian, small lung and refractory ovarian cancers | Zhang et al., 2012, Fund, Joshi 2017 and Shweta et al., 2013 |
| 54 | Quinoline | Aspernigerin | Aspergillus niger | Cynodon dactylon (plant) | Cytotoxic potential to the cancer cell lines nasopharyngeal epidermoid KB with inhibition concentration value (IC50) 22µg | Zhang et al., 2012 |
| 55 | Quinoline | Penicinoline | endophytic fungus Penicillium sp. | Mangrove | Showed cytotoxicity against 95 – D and HepG2 cell lines with IC values 0.57µg/mL and 6.5µg/mL | Zhang et al., 2012 |
| 56 | Quinoline and iso quinoline | Asperfumoid | Aspergillus fumigatus CY018 | Cynodon dactylon (plant) | Antifungal, has specific activity toward Candida albicans | Zhang et al., 2012 |
| 57 | Sesquiterpene alkaloids | Huperzine A | Peccilomyces tenuis YS-13 | Huperzia serrata | Acts as a cholinesterase inhibitor and improves neurotransmitters in the brain | Su et al., 2014 |
| 58 | Spiro – heterocyclic alkaloid | 3’S- pestaloidamide A | Pestalotiopsis sp. | Isodon xerophilus | Exhibited the latent cancer immunotherapy activities | Daley et al., 2021 |
Unbelievably destructive force, occasionally afflict commercial logging action and forest administration attempts. At Mount rainer, white pine blister, a fungal disease caused by Cronartium ribicola frightens more – Heave white bark pine. White pine blister rust was initiated to North America in the early 20th century. It affects branch swelling, branch death, and blights from which orange vesicle appear. Anyways affected trees generally die, occasionally within a few years of infection. Significantly, this fungus depends on two unlike varieties of hosts to full fill its life cycle. Spores sorted by affected white bark pine trees do not go on to affect other trees. In lieu, they infect smaller plants for examples, Gooseberry, Currant and also Indian paintbrush. Parasitic fungi are coming in close connection with their host plants, with the help of motile zoospores; this can break down the cytoplasm from where they will colonize the entire plant.

Non-Endophytes

Saprophytes are also known as Saprotroph or saprobe, organism that feeds on nonliving organic substance called as detritus at an infinitesimal stage. The etymology of the term saprotroph comes from the Greek word ‘Sapros’ means rotten and term ‘trope’ means nourishment. Saprophytic organisms are contemplated endangerment to decomposition and nutrient cycling and inhere fungi, some bacteria and also fungus like organisms called as water molds. Saprophytic fungi are the broadest swarm of fungi, also fungus like organisms called as water molds. Saprophytic fungi are coming in close connection with their host plants, with the help of motile zoospores; this can break down the cytoplasm from where they will colonize the entire plant.

Nonendophytic Fungal Alkaloids

Not only endophytic fungi have future and feature in the synthesis of secondary metabolites particularly alkaloids, but we can also extract alkaloids from non-endophytic fungi. These alkaloids have proven themselves their requirements in pharmacological activities, not only in medicinal field but also in the agricultural field. Under non-endophytic alkaloid we have reported 27 different group of alkaloids. 9 different type of alkaloid are mentioned under indole group of alkaloids, 4 alkaloids are reported under diketopiperazine alkaloids, 4 different alkaloids are mentioned under ergot group of alkaloids, 3 alkaloids are reported under cyclic acid alkaloids, 3 alkaloids are mentioned under pyridine, 2 alkaloids under benzodiazepine alkaloids, 2 alkaloids under quinazoline, 2 alkaloids under sesquiterpene alkaloid, 2 alkaloids under indole diketopiperazine alkaloids, 2 alkaloids are reported under clavine, 1 alkaloid under pyridone, 1 alkaloid under isoquinolone, 1 alkaloid under imidazole, 1 alkaloid under peptide ergot, 1 alkaloid under pyrrole based dimeric alkaloid, 1 alkaloid under pyrrole – imidazole, 2 alkaloid under
Claviceps species produces alkaloids such as Clavine, Elymoclavine – O – β – D – fructoside, γ – ergokryptinine, these alkaloids showed their activities in the production of antimigraine drugs, uterotonics, and also as prolactin inhibitor, antiparkinson agent and pain releivers.

**Table-2: Alkaloids from Non endophytic fungi**

| S. No | Class | Name of Alkaloid | Fungal isolate | Host | Function | Reference |
|-------|-------|------------------|----------------|------|----------|-----------|
| 1     | Azaphilone alkaloid | N-glutaryl/chaetoviridins A – C | Chaetomium globosum | Deep sea sediment sample collected in south china sea | Exhibited a broad spectrum of cytotoxicity toward MGC – 803 and HO8910 with the inhibition concentration (IC50) values of 6.6 and 9.7µM | Sun et al., 2019 |
| 2     | Benzodiazepine alkaloids | Circumdatin A-C | Aspergillus ochraceus | Utilized for Gastrointestinal and central nervous system disorders | Rabba et al., 1999 |
| 3     | Benzodiazepine and indole alkaloids | Circumdatins K and L and 5 – chlorosclerotamide | Aspergillus westerdijkiae | Deep sea | Exhibited cytotoxicity toward human carcinoma cell lines | Peng et al., 2013 |
| 4     | Clavine alkaloids | Fumigaclavine A and B | Aspergillus fumigatus Fres | osprey | Pharmacological functions | Spilsbury et al., 1961 |
| 5     | Clavinet type alkaloid | Triseclavine and isosetoclavine | Elymus type ergot fungus, Agropyrum type fungus | Pennisetum typhoides Rich | Antimicrobial activity | Abe et al., 2014 |
| 6     | Diastereomeric quinolinoalkaloids | Peniprequinolone | Penicillium janczewskii | Marine sample | Exhibited average cytotoxicity on cancer cell lines | He et al., 2005 |
| 7     | Diketopiperazin e alkaloid | Penicillin vinaceum | Penicillium vinaceum | Marine derived | Exhibited antimigratory functions toward the highly metastatic triple negative human breast cancer cells | Asiri et al., 2015 |
| 8     | Diketopiperazin e alkaloid | Chrysopiperazines A and B | Penicillium chrysogenum | Gorgonian derived | Antimicrobial activity | Xu et al., 2019 |
| 9     | Diketopiperazin e alkaloids | Effusin A | Aspergillus effuses H1-1 | Mangrove rhizosphere soil | Showed cytotoxic activities on P388 cells | Gao et al., 2012 |
| 10    | Diketopiperazin e alkaloids | Golmaenone, neoetoclavine A | Aspergillus species | Marine derived | Displayed a significant radical scavenging activity toward 1,1-diphenyl-2-picrylhydrazyl with inhibition concentration (IC50) values of 20 and 24 µM, and also Using as sunscreen | Li et al., 2004 |
| 11    | Dioxopiperazine alkaloid | Dehydroxybisdethiobis(methylthio)giototoxin | Pseudallescheria | Marine derived fungus culture | Showed potent antibacterial activity toward the methicillin – resistant and multidrug – resistant staphylococcus aureus | Li et al., 2006 |
| 12    | Epipolythiodioxopiperazine | Verticillan A, H, gliocladiocin A, C | Bionectriaceae | Exibited cytotoxicity toward a panel of human malignant cell lines | Figueroa et al., 2012 |
| 13    | Ergot alkaloid | Clavine alkaloid, D-lysergic acid and its derivaties and ergopeptides | Claviceps | cereals | Used in pharmaic, industry, where they utilized for synthesis of anti – migraine drugs, uterotonics, prolactin inhibitors and antiparkinsonian agents | Halova et al., 2013 |
| 14    | Ergot alkaloid | Elymoclavine – O – β – D – fructoside | Claviceps strain SD 58 | Pharmacological activities (Pain releivers) | Flieger et al., 1989 |
| 15 | Ergot alkaloids | Clavines, ergonovine alkaloids | Claviceps purpurea | Rice | Tsai et al., 1995 |
|---|---|---|---|---|---|
| 16 | Ergot and clavine alkaloids | Chanoclavine, agroclavine, peniclavine, elymoclavine, ergonovine, ergonovinine | Balansia epichole | Smut grass | Bacon et al., 1979 |
| 17 | Imidazolone alkaloids | Tricladins A and B | Tricladium species | Exhibited marginal cytotoxicity toward MDA – mh-231 human breast cancer cells | Zoua et al., 2011 |
| 18 | Indole 2.5 – diketopiperazine alkaloids | Eurotiumins A – E | Marine derived fungus | Exhibited important radical scavenging functions toward DPPH | Zhong et al., 2018 |
| 19 | Indole alkaloid | Communesins G and H | Penicillium rivalum Frisvad | Inactive in antimicrobial, antiviral and anticancer assays | Dalsgaard et al., 2005 |
| 20 | Indole alkaloid | 7- chlorofischerindoline | Neosartorya hiratsukae | Exhibited antibacterial and cytotoxic activity | Pulka et al., 2020 |
| 21 | Indole alkaloids | Hirsutelones A – E alkaloids | Hirsutella nivea BCC2594 (insect pathogenic fungus) | Exhibited important growth inhibitory activity toward Mycobacterium tuberculosis H37Ra | Isaka et al., 2005 |
| 22 | Indole alkaloids | Notoamides A-D | Aspergillus species | Notoamides A-C, Exhibited average cytotoxicity toward cancer cell lines | Kato, et al. 2007 |
| 23 | Indole alkaloids | Shearinines D, E, and F | Penicillium Janthinellum BioRage | Induce apoptosis in human Leukemia HL-60 cells | Smetanina et al., 2007 |
| 24 | Indole alkaloids | 17-epi-notoamides Q and M | Aspergillus species | Exhibited antibacterial activity toward Staphylococcus epidermidis | Chen et al., 2013 |
| 25 | Indole alkaloids | Fumigatosides E and F | Aspergillus fumigatus | Deep sea | Showed antifungal activity | Limbadri, et al., 2018 |
| 26 | Indole alkaloids | Glyantrypine | Cladosporium species, PJX-41 | Mangrove derived fungus | Showed important effects toward influenza virus A (H1N1) | Peng et al., 2013 |
| 27 | Indole alkaloids | Chaetoglobinol A, Chaetocochin J | Chaetomium globosum | Rice culture | Showed antibacterial activities toward Bacillus subtilis | Xu et al., 2015 |
| 28 | Indole alkaloids | 4-(3-indolyl) butane-1,2,3-triol; 3-(3,3-diindolyl) propane-1,2-diol; and 3-(3-indolyl) propane - 1,2,3-triol | Balansia epichole (Weese) | Laboratory culture | Parasitizes pasture grasses | Porter et al., 1977 |
| 29 | Indole based cytchalasankaloids | Armoclaeglobines A and B | Chaetomium globosum | Anthropod derived, Armadillidi um vulgar | Anticancer activity on human cell lines | Chen et al., 2015 |
| 30 | Indole diketopiperazine alkaloids | Spirotryprostatins C-E, 13-oxoverruculogen | Aspergillus fumigatus | Holothurian | Exhibited cytotoxic activities | Wang et al., 2008 |
| 31 | Isoechimulin type alkaloids | Neoechimulin A, Preeechimulin, Isoechimulin A | Nigrospora genus | Soft coral | Showed antifouling activities toward the larval settlement of barnacle Balanus Amphitrite | Sun et al., 2014 |
| 32 | Isoquinoline alkaloid | Ampullosine | Sepedonium ampullosorum | Exhibited antifungal activity toward the phytopathogenic fungus Cladosporium cucumerinum | Quang et al., 2010 |
| 33 | Mixture of quaternary alkaloid | Tannic, caffeic and ferulic acids | Argemone Mexicana | Exhibited antifungal activity | Singh et al., 2010 |
| 34 | Pentacyclic spiroindolinone alkaloid | Citrinadin A | Marine derived fungus, Penicillium citrinum | Marine red alga | Showed antimicrobial activity | Tsuda et al., 2004 |
| 35 | Peptide ergot alkaloid | γ-ergokryptinine | Claviceps purpurea CCM 8059 | Used in agriculture and medical fields | Cvak et al., 2005 |
| No. | Alkaloids/Compounds                          | Source                | Activity/Pharmacology                                                                                           | References |
|-----|---------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------|------------|
| 36  | Piperazine alkaloid                         | Herquiline alkaloid   | Penicillus herquei Fg-372 Soil sample collected at Saitama Prefecture, Japan Inhibits blood platelet aggregation induced by adenosine diphosphate | Omura et al., 1979 |
| 37  | Prenylated indole alkaloids                 | Asperversiamides      | Aspergillus versicolor Marine derived Showed anti – inflammatory activities | Li et al., 2018 |
| 38  | Prenylated indole alkaloids                 | 17 – O – ethynloamide M | Aspergillus sulphureus and Isaria fiesa Marine derived fungi Inhibit the formation of colony of the human prostate malignant cells 22Rv1 at non – cytotoxic of 10µM | Aliyutullah et al., 2018 |
| 39  | Prenylated indole alkaloids                 | Speramides A          | Aspergillus ohracexus KM007 Fresh water derived Displayed moderate activity toward Pseudomonas aeruginosa with a minimum inhibition concentration (MIC) value of 0.8µM | Chang et al., 2016 |
| 40  | Pyridinone alkaloid                         | 1,4-dihydroxy-5-phenyl-2-pyridinone alkaloid | Septoria pistaciunum Showed average in vitro antimalarial activities toward chloroquine – sensitive (D6) and resistant (W2) strains of plasmodium falciparum and also active toward both methicillin – sensitive and methicillin – resistant staphylococcus aureus | Kumariahmy et al., 2010 |
| 41  | Pyridone alkaloid                           | Arthropyrone D – K    | Arthrinium sp. UJNMF0008 Deep sea derived Exhibited Average to significant antibacterial activity toward Mycobacterium smegmatis and Staphylococcus aureus and also exhibited antimalarial activity toward two human Osteosarcoma cell lines | Bao et al., 2018 |
| 42  | Pyridone alkaloid                           | Militarinones D       | Paeclomyces militaris Displayed cytotoxic activities and negligible neurotogenic effect in PC – 12cells | Schmidt et al., 2003 |
| 43  | Pyridone alkaloids                          | Arthropyrone A - C    | Arthrinium arundinis– ZDS1 – F3 Sponge derived Antimicrobial activity | Wang et al., 2015 |
| 44  | Pyrrole – imidazole alkaloids               | Fusarin species       | Fusarin species Antifungal agent | Kato et al., 1996 |
| 45  | Pyrrole based dimeric alkaloid              | Hirsutellone A        | Trichoderma gelatinosum BCC7579 Anti - tubercular agent | Supothina et al., 2007 |
| 46  | Pyrrolidine alkaloids                       | Aegyptolidesines A and B | Aspergillus eigtyipetus Cotton textile yield Exhibited average cytotoxic effect on murine lymphoma tumor cell line | Ibrahim et al., 2015 |
| 47  | Pyrrolidine alkaloids                       | Ascosalpyrrolidine A  | Ascochyla saltitornae (obligate marine fungus) Green alga Ulva species Showed anti-plasmodial effects against Plasmodium falciparum strains K1 and NF 54, and also exhibited antimicrobial activity and hindering tyrosine Kinase P63α | Osterhage et al., 2000 |
| 48  | Quinazoline alkaloid                        | Aurantiomides A-C     | Penicillium aurantiogriseum sp0-19 Sponge Exhibited average cytotoxicity toward HL-60, P388 and BEL-7402 cell lines | Xin et al., 2007 |
| 49  | Quinazolinone alkaloids                     | Penipanoids A, B and C | Penicillium paneum SD – 44 Marine Sediment – derived Exhibited antimicrobial activity | Li et al., 2011 |
| 50  | Sesquiterpenoid alkaloid                    | Eurochevalierinealkaloid | Eurotium chevalieri Showed antimalarial functions toward Mycobacterium tuberculosis, and also exhibited antimalarial activity toward cancer cell lines | kanokmedh akul et al., 2011 |
| 51  | Spiroindolinone alkaloids                   | Cycloexpansamines A and B | Penicillium sp. (SP-5292) Moderately inhibited the protein’s activity Tyrosine phosphatase 1B | Lee et al., 2015 |
| 52  | Tyrosine alkaloids                          | Gymnstatin Z, Phomacin B and Tritecone D | Westerdykellae dispersa Marine sediment Exhibited antibacterial and cytotoxic activities on human malignant cancer cell line | Xu et al., 2017 |
| 53  | Zwitterionic sesquiterpene alkaloid          | Consoramides A – C    | Irpex consors Culture broth Exhibited antibacterial and antioxidant properties | Kim et al., 2021 |
APPLICATIONS

1. BIOLOGICAL ROLES OF ENDOPHYTIC FUNGI

The potentiality of endophytic fungi is to synthesize new and notable bioactive secondary metabolites. These are more significant in the field of Pharmaceutical, industrial and agriculture. The several natural resources synthesized by endophytic fungi contain identical structures and bioactivities toward different diseases. Instead of a vast bund, this dedicates huge capabilities for oppression of secondary yields for medicinal, agricultural and industrial utilization.

2. NUTRIENT PEDALLING

It is an important procedure that appears enduringly to balance nutrients and wreak them accessible for each element of the environment.

The decadence of the dead biomass evolved into one crucial step to carryback used nutrients to the ecosystem, which in return else becomes available to the living beings. The primary significant characterizations in biodegradation to the trashery of its host plants. They have capacity to disintegrate involute substances into candid form.

Another significant characterization is bioremediation, which explains as a custom of uncapping of pollutants and eyas from the atmosphere by the utilize of microorganisms. It depends on the utilize of microorganisms. It depends on the life procedure of microbes to disintegrate these wastes substances and it has become contingent due to innumerable microbial variety.

3. PHOTOSTIMULATION

Endophytes also takepart in the uptake of necessary nutrients essential for plant growth. They educe uptake of Nitrogen and in giant rescue adjustment to Phosphorous blemish. A novel strain of fungus Cladosporium sphaerospermum extracted from the glycine max (L) Merr roots. Exhibited the aura of higher aggregates of bioactive GA3, GA4 and GA7, which persuade inordinate plant growth in both rice and soyabean types. The endophytes roles are thoroughly recorded for harborage of plant in soil, absorption of nutrient storage, water and ion and vegetative growth of plants, the root system is in close relationship with a broad range of soil microbial populations.

4. ENDOPHYTES IN TISSUE CULTURE

Endophytes are principally precious to the host plants and for plant tissue culture. The ideal host plants and for plant tissue culture. The ideal goal of tissue culture is to grow uncontaminated plants. Even after stature fumigation of the explants, autoclaving and ultraviolet treatment of nutrient medium for tissue culture, endophytic fungi/bacteria/actinomycetes start developing from tissue cultured explant. These endophytes are commonly contemplated as pollutants impacting in complete waste of time, media and explants and also imperiled species of microbes, can be protected by this technique. Also, endophytic species constitution and plant genotype in conjunction under tissue culture circumstances are the basic ingredient for accomplishment of plant tissue cultures with promoted resumption potentiality. Interconnection between the endophytes and particular secondary compounds filtered from plant may be an utmost surface for darkening or browning and cell death, some endophytes were extracted in broth / cultures from roots and plant photosynthetic tissues.

5. ANTIVIRAL ACTIVITY

The alluring utilize of antibiotic products from endophytic fungi are the obstruction of viral growth. Two novel human cytomegalovirus protease hinders, cytolic acids A and B were illuminated by using mass spectrometry and nuclear magnetic resonance techniques and obtained to be effective toward virus growth. Some metabolites from endophytic fungi of xerophytic plants serve as a feasible source for recognizing paladin inhibitors of Human Immunodeficiency virus 1 replication.

6. ANTICANCER ACTIVITY

Paclitaxel and some of its derivatives indicate the top crucial category of antitumor agents generated by endophytes. The method of work of paclitaxel is to intercept tubulin molecules from depolymerizing throughout the cell division procedure. It is the first billion dollars anticancer drug in the world and which is utilized to trat a numerous tissues of human proliferating disease. Taxomyces andreanae lay out an another for synthesis of taxol through torreyanic acid is another significant antitumor agent synthesized from P. microspore extract/ed from T. taxifolia.

Hypocera Lixii, a novel endophytic fungus synthesized Cajanol, an anticancer agent, which is extracted from Cajanus cajan. First time, the endophytic fungus M. fragilis is capable to synthesize these bioactive metabolites, scilicet, Podophyllotoxin and Kaempferol. Also, Guanacastane diterpenoids described from the plant endophytic fungus Cercospora species.

7. ANTIDIABETIC ACTIVITY

A non-peptidal fungal metabolite was extracted from an endophytic fungus Pseudomassaria species gathered from an African rainforest. The nature has given enormous natural resources, which can be expurgated for their medicinal utilizations. The anti diabetic and hypolipidemic activity of endophytic fungi extracted from Salvadora oleoides in glucose aristocrat, fasting and alloxan fomentation diabetic Wistar albino rats and inquest new antidiabetic drugs.
from fungal endophytes name as Aspergillus species, Phoma species, and some unknown species; those noticeably decrease blood glucose level by glucose endurance test. α – amylase obstructive – generating endophytic actinomycetes from the leaves and stem of Leucas ciliate and Rauwolfia densiflora, two of the popular medicinal plants utilized in the diabetic treatment.

8. IMMUNOSUPPRESSIVE ACTIVITY

An endophytic fungus Fusarium subglutinans extracted from T. wilfordii generates subglutinol A and B, which function as the immunosuppressive agent. Now days, these drugs are used to deter allograft dismissal in transplant patients and in coming days they could be utilized to treat autoimmune disease like rheumatoid arthritis and insulin dependent diabetes. Pestaloside, pestalpyrone and hydroxyl pestalopyrone extracted from P. microspore contains plant toxic features. Pseudomycins are antifungal substances, these are antifungal substances, and these substances exhibited strong effectiveness toward human pathogen Candida albicans, which are peptide antibiotics possessing remarkable amino acids such as L – hydroxy aspartic acid, L -chorothreonine and the two D and L – diaminobutyric acid. Ambuic acid which is a cyclohexanone juncture to the Pseudomycins family extracted from Pestalotiopsis microsporeand effective toward human pathogens. Munumbicins, which is a bioactive substance, extracted from Streptomyces species, which are more effective towards gram negative and as well as gram positive bacteria. Munumbicins E – 4 and E – 5 exhibited antimalarial functions, this was more effective as compared with that of chloroquine.

ACKNOWLEDGEMENT

We thank the college management of St. Joseph’s College (Autonomous), Bangalore for providing the laboratory facilities and constant encouragement.

REFERENCES

1. Abe, M.; Yamatodani, S.; Yamano, T.; & Kusumoto, M. (2014). Relationship between Triseclavine and Isosetoclavine, Bull. Agr. Chem. Soc., 22(1); 59–60, https://doi.org/10.1080/03758397.1958.10857438

2. Afiyatullow, S. S.; Zhuravleva O. I.; Antonov A. S.; Berdyshev D. V.; Pivkin, M. V.; Denisenko, V. A.; Popov, R. S.; Gerasimenko, A. V.; Amsberg G. V.; Dyshlovoy, S. A.; Leshchenko, E. V.; & Yurchenko, A. N. (2018). Prenylated indole alkaloids from co – culture of marine – derived fungi Aspergillus sulphureus and Isaria feline. J Antibiot, 71(10): 846 – 853, https://doi.org/10.1038/s41429-018-0072-9

3. Agusta, A. Wulansari, D.; Nurkanto, A.; & Fatoni, A. (2014). Biotransformation of protoberberine alkaloids by the endophytic fungus Coelomycetes AFKR-3 isolated from yellow moonsheed plant (ArchangelisFlava) Merr. Procedia Chemistry, 13:38-43. https://doi.org/10.1016/j.proche.2014.12.004

4. An, C.Y.; Li X.M.; Li C.S.; M.H. Wang, Xu G.M., & Wang, B.G. (2013). Aniquinazolines A-D, four new quinazolinone alkaloids from marine derived endophytic fungus Aspergillus nidulans. Mar. Drugs, 11(7): 2682-2694, https://doi.org/10.3390/md11072682

5. Asiri, I.A.M.; Badr, J. M.; & Youssef, D.T.A. (2015). Penicilllivinacine, antimigratory diketopiperazine alkaloid from the marine – derived fungus Penicillium vinaceum, Phytochemistry letters,13; 53 – 58, https://doi.org/10.1016/j.phytol.2015.05.014

6. Bacon, C. W.; Porter J. K.; & Robbins J. D. (1979). Laboratory production of Ergot alkaloids by species of Balansa, Microbiology, 113(1); 119 – 126.

7. Bao, J. Zhai, H. Zhu, K. Yu J.H.; Zhang, Y.; Wang, Y.; Jiang C.S.; Zhang, Y.X.; Zhang, Y. Zhang. H. (2018), Bioactive pyridine alkaloids from a deep – sea – derived fungus Arthrithium sp. UJNMF0008, Marine Drugs, 16(5):174, https://doi.org/10.3390/md16050174

8. Barros, F. A. P.; & Edison Filho. (2005). Four Spiroquinazolinone alkaloids from Eupenicillium sp. isolated as an endophytic fungus from leaves of Murraya paniculate (Ruaceae). Biochemical Systematics and Ecology, 33(3); 257 – 268. https://doi.org/10.1016/j.bse.2004.09.002

9. Blankenship J.D., Spiering, M.J., Wilkinson, H., Fannin, F.; Bush, L.P., & Scharld, C.L. (2001). Production of loline alkaloids by the grass endophyte, Neotyphodium uncinatum, in defined media, Phytochemistry, 58(3); 395-401, https://doi.org/10.1016/S0031-1871(01)00272-2

10. Chang, Y. W., Yuan, C. M., Zhang, J.; Liu, S., Cao, P., Hua, H. M., Di, Y. T; Hao, X. J. (2016). Speramides A – B, two new prenylated indole alkaloids from the freshwater – derived fungus Aspergillus ochraceus KM007. Tetrahedron Letters, 57(45):4952 – 4955, https://doi.org/10.1016/j.tetlet.2016.09.071

11. Chen, C.; Zhu, H.; Li X.N., Yang, J.; Wang, J.; Li, G., Li Y.; Tong, Q.; Yao, G.; Luo, Z.; Xue, Y.; & Zhang, Y. (2015). Armochaeglobines A and B, two new indole – based alkaloids from the arthropod derived fungus Chaetomium globosum, Org. Lett, 17(3); 644-647, https://doi.org/10.1021/ol503666b

12. Chen, M.; Shao, C. L.; Fu, X. M.; Xu, R. F; Zheng, J. J; Zhao, D. L.; She, Z. G; and Wang, C. Y. (2013). Bioactive indole alkaloids and phenyl ether derivatives from a marine – derived Aspergillus sp. Fungus, J. Nat. Prod., 76(4); 547 – 553, https://doi.org/10.1021/np300707x
13. Cook, D., Gardner, D. R., & Pfister, J. A. (2014). Swainsonine – containing plants and their relationship to endophytic fungi, J. Agric. Food chem., 62(30); 7326-7334, https://doi.org/10.1021/jf501674r

14. Cvak, L., Jegorov, A., Sedmera, P., Cisarova, I., Cejka, J., Kratochvil, B., & Pakhomova, S. Norleucine. (2005), Norleucine, a natural occurrence in a novel ergot alkaloid γ-ergokryptinine, Springer Nature, 29, 145 – 150,https://doi.org/10.1007/s00726-005-0180-2

15. Daley, S. K., & Cordell. G. A. (2021). Biologically significant and recently isolated alkaloids from endophytic fungi. J. Nat. Prod. 84(3); 871-897 https://doi.org/10.1021/acs.jnatprod.0c01195

16. Dalsgaard. P. W., Blunt. J. W, Munro. M. H. G, Frisvad. J. C., & Christophersen. C. (2005).Communesins G and H, new alkaloids from the Psychrotolerant fungus Penicillium rivalum, J. Nat. Prod., 68(2); 258 – 261, https://doi.org/10.1021/jp049646i

17. Dissanayake. R. K., Ratnaweera. P.B., Williams D., Wijayarathne. C. D, Wijesundera. R. L.C., Dissanayake. R. K., Ratnaweera P.B, Williams D., https://doi.org/10.1021/np049646i

18. Du F.Y., Li X., Li, C.S., & Shang, Z. (2012). Cristatins A-D, new indole alkaloids from the marine – derived endophytic fungus Eurotium cristatum EN -220. Phytochemistry Letters. 22(14): 4650-4653, https://doi.org/10.1016/j.phyto.2012.05.088

19. Du, F.Y., Li X., Li X.M., Zhu L.W., & Wang, B.G. (2017). Indole diketopiperazine alkaloids from Eurotium cristatum EN – 220, an endophytic fungus isolated from the marine alga Sargassum thunbergii. Marine Drugs. 15(2),https://doi.org/10.3390/md15020024

20. Feng, C., & Ma. Y. (2010). Isolation and anti – phytopathogenic activity of secondary metabolites from Alternaria sp. FL25, an endophytic fungus in Ficus carica. Chinese Journal of applied and Environmental Biology, 16(1):76-78, https://doi.org/10.3724/SP.J.1145.2010.00076

21. Figueroa. M., Graf. T.N., Ayers. S., Adcock. A. F., Kroll. D. J., Yang. J, Swanson. S.M, Acuna. U. M, Blanco. E.J.C.D, Agrawal. R., Wani. M.C, Darveau, B.A., Pearce. C. J., Oberlies N. H. (2012). Cytotoxic epiophthidioxopiperazine alkaloids from filamentous fungi of the Bionectriaceae, the journal of antibiotics., 65(11):559-564,https://doi.org/10.1038/jfa.2012.69

22. Flieger. M., Zelenkova. N.F., Sedmera. P., Kren. V., Novak. J., Rylko. V., Sadji, P., & Rehacek. Z. (2004). Ergot alkaloid glycosides from saprophytic cultures of Claviceps, I.Elymoclavine fructosides, J. Nat. Prod., 53(3): 506 – 510, https://doi.org/10.1021/np05063a007

23. Gao H., Liu W., Zhu T., Mo X., Mandi A., Kurtan T., Li J., Ai J., Gu Q. & Li D. (2012). Diketopiperazine alkaloids from a mangrove rhizosphere soil derived fungus Aspergillus effuses H1-1. Org. Biomol. Chem., 10: 9501-9506, https://doi.org/10.1039/C2OB26757H

24. Gao. N., Shang. Z. C., Yu. P., Luo. J., Jian. K. L., Kong. L. Y and Yang. M. H. (2017),Alkaloids from the endophytic fungus Penicillium brevisidianum and their cytotoxic activities, Chinese Chemical Letters, 28(6):1194–1199, https://doi.org/10.1016/j.ccl.2017.02.022

25. Grumi S. D., Cook D., Baucom D., Mottl. W., Gardner D. R., Creamer, R., & Allen, J. G. (2013). Production of the alkaloid Swainsonine by a fungal endophyte in the host Swainsonia canescens, J.Nat.Prod.,76(10): 1984-1988, https://doi.org/10.1021/jp400274n

26. Harwoko, H., Lee, J., Hartmann, R., Mándi, A., Kurtán, T., Müller, W.E.G., Feldbrügge, M., Kalscheuer, R., Ancheeva, E., Daletos, G., Frank, M., Liu, Z., Proksch, P. (2020). Azacoccones F – H, new flavipin – derived alkaloids from an endophytic fungus Epicoccum nigrum MK214079.Fitoterapia146: 104698https://doi.org/10.1016/j.fitote.2020.104698

27. Hawary - El. S. S., Moawad. A. S., Bahr. H. S., Abdelmohsen U. R., & Mohammed. R. (2020). Natural product diversity from the endophytic fungi of the genus Aspergillus. RSC Adv, 10(37); 22058-22079, https://doi.org/10.1039/DORA04290K

28. He, J. Lion. U., Sattler. I., Gollmick F. A., Grabley. S., Cau. J., Meiners. M., Schunke. H, Schaumann. K, Decher. U., & Krohn. M. (2005). Diastereomeric Quinoline alkaloids from the marine derived fungus Penicillium Janczewskii, J. Nat. Prod. 68(9); 1397 – 1399, https://doi.org/10.1021/jp058018g

29. Hulvova H., Gluszka, P., Frebortova, J., & Frebort, I. (2012). Parasitic fungus Claviceps as a source for biotechnological production of ergot alkaloids. Biotechnology Advances, 31(1): 79-89, https://doi.org/10.1016/j.biotechadv.2012.01.005

30. Ibrahim. S. R. M., Mohamed. G. A., Moharram. A. M, Diaa T. A., & Youssef. D. T. A. (2015). Aegyptolidines A and B: New pyrrolidine alkaloids from the fungus Aspergillusaepticytus. Phytochemistry Letters. 12 : 90 – 93, https://doi.org/10.1016/j.phytol.2015.03.001

31. Isaka. M., Rugseree. N., Maithip. P., Kongsaeree. P., Prabpai. S., & Thebtaranonth. Y. (2005). Hirsutellones A- E, antimycobacterial alkaloids from the insect pathogenic fungus Hirustella nivea BCC2594. Tetrahedron., 61(23):5577–5583, https://doi.org/10.1016/j.tet.2005.03.099
32. Jiang, C.S., Zhou, Z.F., Yang X.H., Lan L. F., Gu Y.C., Ye B.P., & Guo, Y.W. (2018). Antibacterial sorbicillin and diketopiperazines from the endogenous fungus Penicillium sp. GD6 associated Chinese mangrove Bruguiera gymnorrhiza. *Chinese Journal of Natural Medicines*, 16(5): 358 – 365. https://doi.org/10.1016/S1875-5364(18)30068-2
33. Kanokmedhakul, K., Kanokmedhakul, S., Suwannatrai, R., Soytong, K., Prabpai, S., & Kongsaeree, P. (2011). Bioactive meroterpenoids and alkaloids from the fungus Eurotium chevalieri. *Tetrahedron*, 67(30): 5461-5468, https://doi.org/10.1016/j.tet.2011.05.066
34. Katoh, Y., Yoshiida, T., Tokue, T., Nojiri Y., Hirota H., Ohita T., Williams R. M., Tsukamoto S. (2007). Notoamides A-D: prenylated indole alkaloids isolated from a marine – derived fungus, Aspergillus sp., Angew. Chem. Int. Ed. Engl., 46(13):2254-2256, https://doi.org/10.1002/anie.200604381
35. Kato, Y., Koshino, H., Uzawa, J., & Anzai, K. (1996). Fungerin, a new antifungal alkaloid from Fusarium sp. (1996). *Bioscience, Biotechnology, and Biochemistry*, 60(12): 2081 – 2083, https://doi.org/10.1271/bbb.60.2081
36. Kim, J. Y., Ki., D. W., Lee, Y. J., Ha, J. S., Kim, J. H., Lee, I. K., & Yun, B. S. (2021). Consoramides A – C, New zwiterionic alkaloids from the fungus Irpex consors, *Mycobiology*, 49(4); 434 – 437, https://doi.org/10.1080/12298093.2021.1924926
37. Koolen, H. H. F., Soares E. R., Dasilva F. M. A., Dealemeida R. A., DesouzaA. D. L., DemedeirosL. S., Filho E. R., Desouza A. Q. L. (2012). An antimicrobial alkaloid and other metabolites produced by Penicillium sp. An endophytic fungus isolated from Mauritia flexuosa Lf. *Quim. Nova*, 35(4); 771-774. https://doi.org/10.1590/S0100-40422012000400022
38. Kuklev, D.V., & Dembitsky, V.M. (2016). Chemistry, origin, antitumor and other activities of fungal homo – dimeric alkaloids, *M J Pharm*, 1(1); 004, ISSN 2474 – 753X
39. Kumara, A., Patil, Deepak., Rajamohanan, P. R., & Ahmad. A. (2013). Isolation, purification and characterization of vinblastine from endophytic fungus Fusarium oxysporum isolated from Catharanthus roseus. PLoS One. 16; 8(9):e71805. https://doi.org/10.1371/journal.pone.0071805
40. Kumara. P. M., Soujanya, K. N., Ravikanth. G., Vasudeva, R., Ganeshiah, K.N., & Shaankar. R. U. (2014). Rohitukine, a chromosome alkaloid and a precursor of flavopiridol, is produced by endophytic fungi isolated from *Diosyoxylum binectariferum* Hook.f and Amoora rohituka (Roxb).Wight and Arn. *Phytotherapy*, 21(4); 541-6,https://doi.org/10.1016/j.phymed.2013.09.019
41. Kumariamy, M., Fronczcek, F. R., Diferriera. Jacob M., Khan, S. I., Nanayakkara. N.P.D. (2010). Bioactive 1, 4-dihydroxy – 5 – phenyl – 2 – pyrinidine alkaloids from Septoria pusticarium, J. Nat. Prod., 73(7):1250 – 1253, https://doi.org/10.1021/np1000939
42. Lee, C., Sohn, J. H., Jang, J. H., Ahn, J. S., H. O.H., J. Baltrusaitis. (2015). Cyclopanamines A, & B: Spiroindololmine alkaloids from a marine isolate of *penicillium* sp (SF – 5292). *The Journal of Antibiotics*, 68; 715–718, https://doi.org/10.1038/ja.2015.56
43. Li, D., Li X. M., Li, T. G., Dang, H.Y., Proksch, P., & Wang, B.G. (2008). Benzaldehyde derivatives from *Eurotium rubrum*, an endophytic fungus derived from the mangrove plant *Hibiscus tiliae*c Chem Pharm Bull (Tokyo) 56(9); 1282–1285, https://doi.org/10.1248/cpb.56.1282
44. Li, H., Sun, W., Deng, M., Zhou, Q., Wang, J., Liu., J., Chen, C., Qi, C., Luo., Z., Xue, Y., Zhu., H., & Zhang, Y. (2018). Asperversiamides, linearly fused prenylated indole alkaloids from the marine derived fungus *Aspergillus versicolor*. *J. Org. Chem.*, 83(15); 8483–8492, https://doi.org/10.1021/acs.joc.8b01087
45. Li, L. Y., Ding, Y., Groth, I., Menzel. K. D., Peschel, G., Voigt, K., Deng. Z. W., Sattler., L., & Lin. W.H. (2008). Pyrrole and indole alkaloids from an endophytic Fusarium incarnatum (HKI00504) isolated from the mangrove plant Aegiceras corniculatum, *Journal of Asian Natural Products Research*, 10(8); 765-770,https://doi.org/10.1080/10286020802031106
46. Li, X.B., Li. L., Zhu. R. X., Li, W, Chang. W. Q., Zhang, L.L., Wang. X. N., Zhao. Z. T., and Lou. H. X. (2015). Tetramic acids and pyridine alkaloids from the endolichenic fungus *Tolypocladium cylindrosporum, J. Nat. Prod.*, 78(9); 2155–2160, https://doi.org/10.1021/np501018w
47. Li, X, Kim, S. K., Nam. K. W., Kang. J. S., Choi. H. D., & Byeng Wha Son. B. W. (2006). A new antibacterial dioxopiperazine alkaloid related to Gliotoxin from a marine isolate of the fungus Psudallescheria. *J Antibiot, 59* (8); 23
48. Li, X.B., Li. L., Zhu. R. X., Li, W, Chang. W. Q., Zhang, L.L., Wang. X. N., Zhao. Z. T., and Lou. H. X. (2015). Tetramic acids and pyridine alkaloids from the endolichenic fungus *Tolypocladium cylindrosporum, J. Nat. Prod.*, 78(9); 2155–2160, https://doi.org/10.1021/np501018w
49. Limbadri. S., Luo. X., Lin. X., Liao. S., Wang. J., Zhou. X., Yang. B and Liu. Y. (2018). Bioactive novel indole alkaloids and steroids from deep sea – derived fungus *Aspergillus fumigatus* SC5102. *Molecules*, 23(9); 2379, https://doi.org/10.3390/molecules23092379
50. Lin X, Ai. W., Li M, Zhou. X., Liao. S., Wang. J., Liu. J., Yang. B., & Liu, Y. (2020).
Cytotoxic alkaloids from the Endophytic fungus Penicillum herquei (1979). Omura., S., Hirano. A., Iwai, Y., & Masuma. R. https://doi.org/10.7164/antibiotics.32.786

"Cytotoxic and antimicrobial indole alkaloids from an endophytic fungus Chaetomium sp. Isolated from Fritillaria unibracteata var.wabensis". Fitotermia, 103:213-221, https://doi.org/10.1016/j.fitote.2015.04.006

"Antiviral alkaloids produced by the mangrove derived fungus Cladosporium sp. SYP-F7950 of Panax notoginseng. RSC Adv 9:28754-28763, https://doi.org/10.1039/C9RA047447F

"Two new antileishmanial diketopiperazine alkaloids are also produced by an endophytic fungus of the genus Neosartorya hiratsukae. J. Nat. Prod, 76(6):1133 – 1140, https://doi.org/10.1021/np400200k

"Alkaloids from the deep-sea-derived fungus Aspergillus westerdijkiae DFFSCS013. J. Nat. Prod, 76(5); 983 – 987, https://doi.org/10.1021/np040132m

"The genus Epichole and its toxic effects in livestock". Toxins, 8(2):47,https://doi.org/10.3390/toxins8020047

"Antiviral alkaloids produced by the mangrove derived fungus Ficus carica. J. Nat. Prod. 76(6):1133 – 1140, https://doi.org/10.1021/np400200k

"Indole and diterpene alkaloids produced by endophytic fungi of the genus Ficus carica and their toxic effects in livestock. Toxins, 8(2):47,https://doi.org/10.3390/toxins8020047

"Indole alkaloids from the mangrove fungus derived from the medicinal plant Bauhinia guianensis, Natural Product Research, 27(18): 1633-1638, DOI: 10.1080/14786419.2012.750316

"Indole alkaloids from Balansia epichole (Weesee). J. Agric. Food Chem., 25(1); 88-93, https://doi.org/10.1021/jf60209a043

"Nano – and microscale drug delivery systems. https://doi.org/10.1016/B978-0-323-52727-9.00023-6
70. Quang, D. N., Schmidt, J., & Porzel, A. (2010). Ampullinosine, a new isoquinoline alkaloid from Sepedonium ampullosporum (Ascomycetes), Natural Product Communications, 5(6); 869 - 872.https://doi.org/10.1177/1934578X100500609
71. Rahbaek, L., Breinholt, J., Frisvad, J. C., & Christensen, C. (1999). Circumdatin A.B.C: Three new benzodiazepine alkaloids isolated from a culture of the fungus Aspergillus ochraceus, J. Org. Chem., 64(5):1689–1692, https://doi.org/10.1021/jo981536u
72. Roy, A. (2017). A review on the alkaloids an important therapeutic compound from plants. International Journal of Plant Biotechnology, 3(2); 1–9.
73. Schmidt, K., Riese, U. L. Z., & Hamburger, M. (2003). Novel Tetramic acids and pyridine alkaloids, militarinones B, C., & D from the insect pathogenic fungus Paecilomyces martialis, J. Nat. prod., 66(3); 378 – 383, https://doi.org/10.1021/np020430y
74. Shankar, G. V., Lingam, Y. M., Yu. H. N., & Liu, W. H. (2010). Diketopiperazine alkaloids from Penicillium sp. HS-3, an endophytic fungus in Huperzia serrata. Helvetica Chimica Acta. 93(4):772 – 776, https://doi.org/10.1002/hlca.200900331
75. Shweta, S., Gurumurthy, B. R., Ravikanth, G., Ramanan, U. S., & Shivananda, M. R. (2012). Endophytic fungi from Miquella dentate Bedd., produce the anti – cancer alkaloid, camptothecine. Phytomedicine, 15; (203-4):337-42,https://doi.org/10.1016/j.phymed.2012.11.015
76. Singh, S. Singh. A., Jaiswal, J., Singh T. D., Singh V. P., Pandey, V.B., Tiwari, A., & Singh. U. P. (2010). Antifungal activity of the mixture of quaternary alkaloids isolated from Argemone Mexicana against some phytopathogenic fungi. Archives of Phytopathology and Plant Protection, 43(8):769 - 774, https://doi.org/10.1080/03235400802176159
77. Smetanina, O.F., Kalinovsky A.I., Khudyakova Y. V., Pivkin M.V., Dmitrenok. P. S., Fedorov. S. N., Ji. H., Kwak, J. Y., & Kuznetsova. T. A. (2007). Indole alkaloids produced by a marine fungus isolate of Penicillium janthinellum Biourge, J.Nat.Prod., 70(6):906-909, https://doi.org/10.1021/np060396d
78. Song, R., Wang, J., Sun, L., Zhang, Y., Ren, Z., Zhao, B., and Lu. H. (2019).The study of metabolites from fermentation culture of Alternariaoxystropis, BMC Microbiol. 19(1):35. https://doi.org/10.1186/s12866-019-1408-8
79. Spilsbury, J.F., & Wilkinson, S. (1961). The isolation of festuclavine and two new clavinet alkaloids from Aspergillus fumigatusFres, J. Che. Soc., (0)2085–2091, https://doi.org/10.1039/JR9610002085
80. Su, J. and Yang. M. (2015). Huperzine A production by Paecilomyces tenuis YS-13, an endophytic fungus isolated from Huperzia serrata. Nat Prod Res., 29(11):1035-41,https://doi.org/10.1080/14786419.2014.980245
81. Sun, C., Ge, X., Madusiss, S., Zhou, L., Yu, G., Che, Q., Zhang, G., Peng, J., Gu, Q., Zhu T. Li, D. (2019). New glutamine containing Azaphilone alkaloids from deep sea derived fungus Chaetomium Globosum HDN151398, Mar Drugs. 17(5):253, https://doi.org/10.3390/md17050253
82. Sun, X. P., Xu. Y., Cao, F., Xu R. F., Zhang. L. X., & Wang. C. Y. (2014). Isoeochinulin – type alkaloids from a soft coral derived fungus Nigrosporaoryzae. Chemistry of Natural Compounds, 50; 1153 – 1166, https://doi.org/10.1007/s10600-014-1189-0
83. Supothina, S., Isaka, M., & Wongsa, P. (2007). Optimization of culture conditions for production of the anti – tubercular alkaloid hirsutellone A by Trichoderma gelatinosum BCC7579. Lett Appl Microbiol., 44(5):531–537, https://doi.org/10.1111/j.1742-765X.2006.02089.x
84. Tsai H.F., Wang H., Gebler J.C., Poulter C.D., & Schardt C.I. The Claviceps purpurea gene encoding dimethylallyltryptophan synthase, the committed step for ergot alkaloid biosynthesis. From the chemist to the farmer: 2012, 19(1):119–125, https://doi.org/10.1006/bbrc.1995.2599
85. Tsuchinari, M., Shimanuki, K., Hiramatsu, F., Murayama, T., Koseki, T., & Shiono. Y. (2007). Fusapyridons A and B, Novel Pyridone alkaloids from an endophytic fungus, Fusarium sp. YG- 45, Z.Naturforsch.62b:1203–1207, https://doi.org/https://doi.org/10.1515/znb-2007-0916
86. Tsuda, M., Kasai, Y., Komatsu, K., Sone, T., Tanaka, M., Mikami, Y., & Kobayashi, J. (2004). Citrinadin A, a novel pentacyclic alkaloid from marine – derived fungus Penicillium citrinum, Org.Lett., 6(18):3087-3089. https://doi.org/10.1021/ol048900y
87. Verma. V. C., Lobokovsky E., Gange. A. C., Singh. S. K., and Prakash. S. (2012). Piperine production by endophytic fungus Periconia sp. Isolated from Piperlongum L.,The journal of antibiotics. 64(6):427-431, https://doi.org/10.1038/ JA.2011.27
88. Wang, A., Zhao, S., Gu G., Xu D., Zhang X., Lai, D., & Zhou, L. (2020). Rhizovagine A, an unusual dibenzo – α – pyrone alkaloid from the endophytic fungus Rhizopycnis vagum Nital22. RSC Adv., 10: 27894-27898, https://doi.org/10.1039/DORA05022A
89. Wang, F., Fang Y., Zhu, T., Zhang, M., Lin A., Gu, Q., & Zhu, W. (2008). Seven new prenylated indole diketopiperazine alkaloids from holothurian derived fungus Aspergillus fumigatus. Tetrahedron64(4): 7986–7991, https://doi.org/10.1016/j.tet.2008.06.013
90. Wang, J., Wei, X., Qin, X., Lin, X., Zhou, X., Liao, S., Yang, B., Liu, J., Tu, Z., Liu, Y. (2015). Arthropyrone A – C, pyridine alkaloids from a sponge-derived fungus *Arthrinium arundinidis* ZSDS1 – F3. Org. Lett. 17(3):656 – 659, https://doi.org/10.1021/ol503646c

91. Wang, X. J., Min, C. L., Ge, M. and Zuo, R. H. (2014). An endophytic Sanguinarine-producing fungus from Macleaya cordata, *Fusarium proliferatum* BLHS1. Cur. Microbiol. 68(3):336-341, https://doi.org/10.1007/s00284-013-0482-7

92. Wijeratne, E. M., He, H., Franzblau, S. G., Hoffman, A. M. and Gunatilaka, A. L. (2013). Phomapyrrolidiones A – C, antitubercular alkaloids from the endophytic fungus *Phoma sp.* NRRL 46751. J. Nat. Prod. 76, (10): 1860 – 1865, https://doi.org/10.1021/np400391p

93. Xin, Z. H., Fang, Y., Du, L., Zhu, T., Duan, L., Chen, J., Gu, Q. Q., Zhu, W. M. (2007). Aurantimiones A-C, Quinazoline alkaloids from the sponge – derived fungus *Penicillium aurantiogriseum* SP-19. J. Nat. Prod. 70(5): 853-855, https://doi.org/10.1021/np060516h

94. Xu, G. B., He, G., Bai, H. H., Yang, T., Zhang, G. L., Wu, L. W. and Li, G. Y. (2015). Indole alkaloids from *Chaetomium globosum* J. Nat. Prod. 78, (7):1479 – 1485, https://doi.org/10.1021/np5007253

95. Xu, D., Luo, M., Liu, F., Wang, D., Pang, X., Zhao, T., Xu, L., Wu, X., Xia, M., Mand Yang, X. (2017). Cytochalasain and tyrosine derived alkaloids from the marine sediment derived fungus *Westerdykella dispera* and their bioactivities. Sci Rep 7:11956, https://doi.org/10.1038/s41598-017-12327-1

96. Xu, W. F., Mao, N., Xue, X. J., Qi, Y. X., Wei, M. Y., Wang, C. Y., & Shao, C. L. (2019). Structures and Absolute configurations of Diketopiperazine of alkaloids Chrysopiperazines A – C from the Gorgonian – derived *Penicillium Chrysogenum* fungus. Mar. Drugs. 17(5):250, https://doi.org/10.3390/md17050250

97. Yang, S. X., Xiao, J., Holstein, L. J., Dittrich, B., Zhang, Q., Gao, J. M. (2012). Fusarimine, a novel polyketide isoquinoline alkaloid, from the endophytic fungus *Fusarium* sp. LN12, isolated from *Melia azedarach*. Tetrahedron Letters.53(47):6372-6375, https://doi.org/10.1016/j.tetlet.2012.09.031

98. Yunitsio, P., Rusman, Y., Saepudin, E., Suwarso, W. P., & Sumaryono, W. (2014). Alkaloid (Meleagrine and Chrysogine) from endophytic fungi (*Penicillium* sp.) of *Annona squamosa* L., Pak J Biol Sci., 17(5):667-674, https://doi.org/10.3923/pjbs.2014.667.674

99. Zhang, P., Li, X. M., Liu, H., Li, X., & Wang, B. G. (2015). Two new alkaloids from *Penicillium oxalicum* EN-201, an endophytic fungus derived from the marine mangrove plant *Rhizophora stylosa*, Phytochemistry Letters, 13:160-164, https://doi.org/10.1016/j.phytol.2015.06.009

100. Zhang, P., Yuan, X. L., Du, Y. M., Zhang, H. B., Shen, G. M., Zhang, Z. F., Liang, Y. J., Zhao, D. L. and Xu, K. (2019). Angularly prenylated indole alkaloids with antimicrobial and insecticidal activities from an endophytic fungus *Fusarium sambucinum* TE – 6L. J Agri Food Chem., 67(43):11994 – 12001, https://doi.org/10.1021/acs.jafc.9b05827

101. Zhang, P., Li, X. M., Wang, J. N., & Wang, B. G. (2015). Oxepine – containing diketopiperazine alkaloids from the algal derived endophytic fungus *Paecilomyces varioti* EN – 291, Helvetica Chimica Acta., 98(6):800 – 804, https://doi.org/10.1002/hilc.201400328

102. Zhang, Y., Han, T., Ming, Q., Wu, L., Rahman, K and Qin, L. (2012). Alkaloids produced by endophytic Fungi. Nat Prod Commun. 7(7):963-968, https://doi.org/10.1177/1934578X1200742

103. Zheng C.J., Li L., Zou J.P., Han T., Qin L. P. (2011). Identification of a quinazoline alkaloid produced by *Penicillium vinaceum*, an endophytic fungus from *Crocus sativus*. Pharmaceutical Biology 50(2): 129 – 133, https://doi.org/10.3109/13880209.2011.569726

104. Zhong, W. M., Wang, J. F., Shi, X. F., Wei, X. Y., Chen, Y. C., Zeng, Q., Xiang, Y., Chen, X. Y., Tian, X. P., Xiao, Z. H., Zhang, W. M., Wang, F. Z., & Zhang, S. (2018). Eurotumins A – E, five new alkaloids from the marine derived fungus *Eurotium sp*. SCSSIO F452. MarDrugs.16(4):136, https://doi.org/10.3390/md16040136

105. Zhu, M., Zhang, X., Feng, H and Che, Q. (2016). Campyridones A-D, pyridone alkaloids from a mangrove endophytic fungus *Campylocarpon sp*. HDN13-307, Tetrahedron, 72(37):5679-5683, https://doi.org/10.1016/j.tet.2016.07.080

106. Zhu, M., Zhang, X., Feng, H., Dai, J., Li, J., Che, Q., Gu, Q., Zhu, T. and Li, D. (2016). Penicilisulfuranols A – F, alkaloids from the mangrove endophytic fungus *Penicillium janthinellum* HDN13 – 309. J. Nat. Prod. 80(1):71-75, https://doi.org/10.1021/acs.jnatprod.6b00483

107. Zhou, R., Wei, C., Xueia, Zhang, X., Zhou, D., and Xu, J. (2021). Alkaloids from endophytic fungus *Aspergillus fumigatus* HQD24 isolated from the Chinese mangrove plant *Rhizophora mucronate*. Nat Prod Res. 1-5, https://doi.org/10.1080/14786419.2021.1916017

108. Zhou, X., Liu, S., Zheng, Z., Zhang, H., Chen, X., Liu, X., & Li, E. (2011). Two new imidazoline – containing alkaloids and further metabolites from the ascomycete fungus *Tricladium* sp. Chem Biodivers. 8(10):1914 – 1920, https://doi.org/10.1002/cbdv.201000372