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Review Article

Antibacterial and antifungal activities of medicinal plant species and endophytes

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ABSTRACT

Systemic bacterial and fungal infections in recent years due to the increasing number of debilitating diseases immune system such as AIDS, blood malignancies, overdose, corticosteroid drugs, and broad-spectrum antibiotics has been raised. There is a prevalence of acute and subsequent candida infections with drug-resistance properties such as fluconazole. Due to the prevalence and spread of fungal and bacterial diseases, the effort to find treatments has increased more than before. The use of plant compounds for the therapy of fungal and bacterial diseases is effective due to their unique biocompatible and bioavailable. The trend toward new antifungal and antibacterial agents being introduced to the market remains small, while resistance to many antibiotics is emerging, especially in patients receiving long-term treatment. Considering the enormous antimicrobial potentials of natural compounds isolated from plants and endophytes and screening of new antibiotics for various pharmaceutical applications as an alternative source remains largely unknown. Endophytes and medicinal plant species have main primary and secondary metabolites suitable to hindrance or inactivation of pathogens. Recently, various studies about the antibacterial and antifungal activities of these metabolites have been reported. For this purpose, in this review, antibacterial and antifungal activities of endophytes of *Pestalotiopsis* genus and medicinal plant species of *Zingiber* and *Hydnora* genera have been discussed according to recent studies.

1. Introduction

Systemic bacterial and fungal infections in recent years due to the increasing number of debilitating diseases immune system such as AIDS, blood malignancies, overdose, corticosteroid drugs, broad-spectrum antibiotics specifically in the case of multidrug-resistant bacteria, etc [1-4], especially for hospitalized patients has been raised. For instance, there is a prevalence of acute and subsequent candida infections with drug-resistance properties such as fluconazole [5]. Therefore, it is a critical affair to apply alternative effective compounds in particular, primary and various secondary metabolites of medicinal plants (carotenoids, alkaloids, phenolic compounds, and flavonoids; Figure 1a) [6], and fungal endophytes [7] (Figure 1b) for treatment and prevention of fungal and bacterial infections without side effects of antibiotics [8, 9].

2. The endophytic fungus

2.1. Pestalotiopsis

As mentioned in the introduction section, endophytes can contribute to their host plant species by producing various metabolites to protect and survive the plant [10]. In addition, the main function of this endophyte can be to produce a variety of biologically active

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molecules and new metabolites in medicine, agriculture and industrial complexes that have a variety of micro and nano applications [11-14].

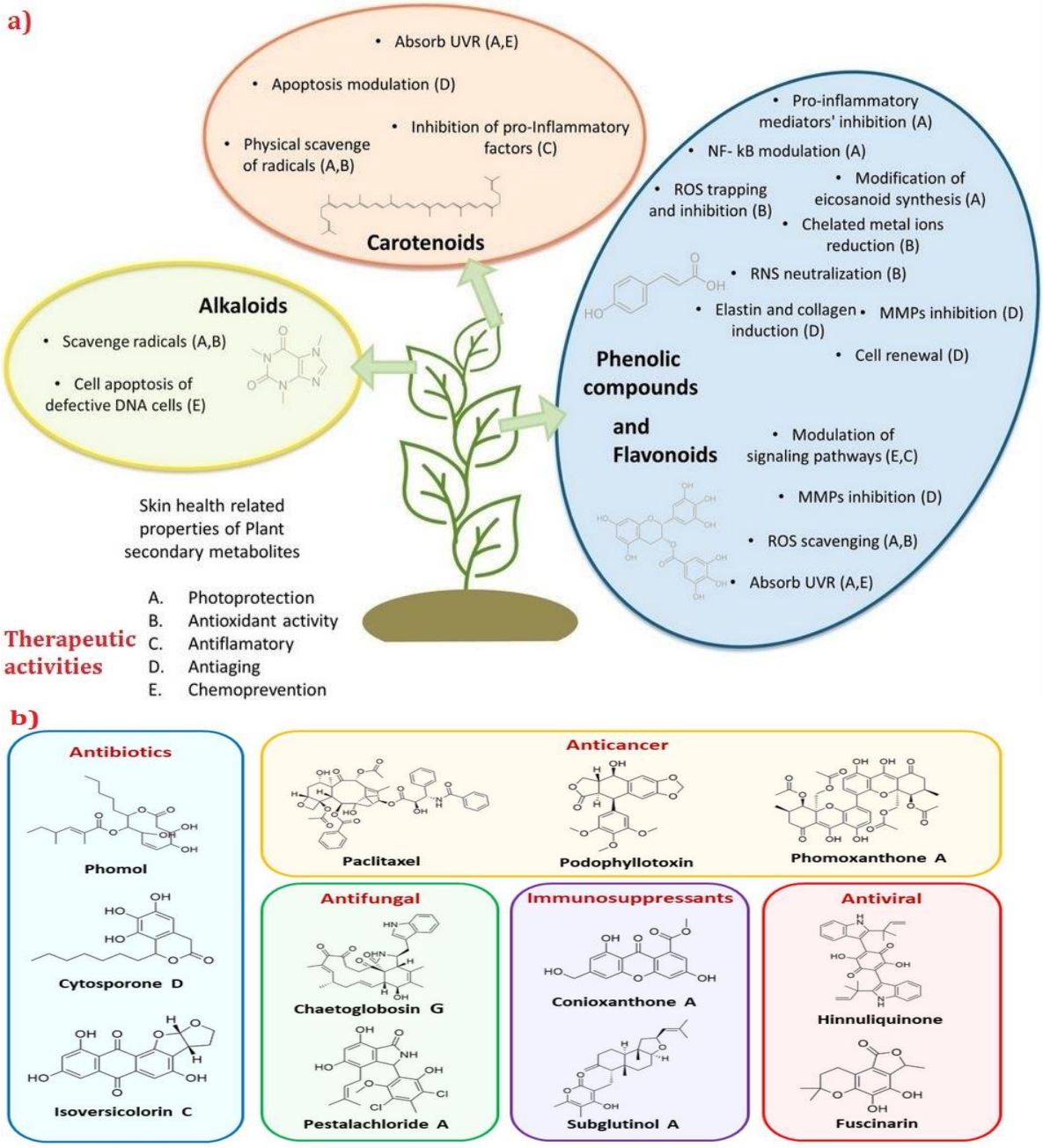

Fig. 1. various secondary metabolites of medicinal plants (a) [6] and fungal endophytes (b) [7] with therapeutic activities (Copyright permission under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/)).

The recurrence of fungal infections encountered during allogeneic bone marrow transplantation, cancer treatment and organ transplantation has necessitated the discovery of more efficient and better compatible antifungal compounds. There are a very limited number of antifungal compounds in action against various forms of local and systemic fungal infections [15, 16]. Pestalotiopsis is an important genus of an ascomycete, and several species of this genus have been identified to produce biologically active compounds for various biological properties, including antimicrobial, antifungal,

antiviral, anti-cancer, and antioxidant activities [17].

Some studies reported antifungal metabolites of this genus include a new lactone monoterpene, (3R, 4R, 6R, 7S) -7-hydroxy-3,7-dimethyl-oxabicyclo nonan-2-one, with a combination A known related 3 R, 4R-3- (7-methyl cyclohexenyl) -propanoic acid) was discovered from the endophytic fungus *Pestalotiopsis foedan* obtained from *Bruguiera sexangula*, a mangrove tree or shrub, in Hainan. These compounds showed antifungal activity against *Botrytis cinerea* and *Phytophthora nicotianae* at minimum inhibition concentration (MIC) values of 3.1 and 6.3 µg/ml, while the known antifungal drug, ketoconazole showed comparable activity (MIC 3.1 µg/ml). The effects of *Candida albicans* at MIC 50 µg/ml show positive efficacy while ketoconazole MIC at 6.3 µg/ml has positive efficacy [18].

3. Plants

3.1. *Zingiber* genus

Zingiber cassumunar Roxb. belongs to the *Zingiberaceae* family and is a perennial herbaceous plant that consists of an underground part consisting of rhizomes. In Thailand, Indonesia and other Asian countries, *Z. cassumunar* is traditionally used as a medicinal plant in folk remedies, for example, to treat various diseases such as inflammation, including arthritis, rheumatism, sprains, Respiratory problems such as asthma and cough and pain due to musculoskeletal disorders, menstruation or gastrointestinal tract are main medicinal applications of these plants [19].

Various types of compounds found in *Z. cassumunar* such as phenylbutenoids, curcuminoids, sesquiterpenoids, benzaldehydes, quinones and essential oils containing monoterpenoids have been identified that are used in the treatment of many of these diseases. Phenylbutenoids are characteristic compounds of this plant and have been isolated using various separation techniques, including silica gel or reverse phase column chromatography, recrystallization, and thin-layer chromatography. Extracts and compounds of *Z. cassumunar* have activities, biologically diverse, including antioxidant activity [20].

In addition to inflammation, anti-cancer, neuroprotective/neurotrophic, cosmetic, and antifungal/antibacterial activities, a review of the clinical effects of various formulations using Plai (*Z. cassumunar*) on pain relief, acne treatment, and antihistamines has been performed. But there has been no previous report summarizing the accumulated studies in the phytochemicals literature and the in vitro and in vivo biological properties of *Z. cassumunar*, including our previous studies that have contributed to the discovery of chemical diversity and biological activity of this plant [21]. The oil of *Z. cassumunar* rhizomes has high antifungal activity (inhibition zone of 11.7-15.7 mm) and its effectiveness is much higher than the five strains of yeast, *Saccharomyces cerevisiae*, *Cryptococcus neoformans*, *C. albicans*, and *Candida tropicalis* [22].

Z. cassumunar essential oil, containing 32% volume of terpinene-4-1 as its main constituent, showed antibacterial activity against a wide range of bacteria Gram-positive: *Staphylococcus aureus* ATCC 29737, *Streptococcus pyogenes*, *Bacillus subtilis* ATCC28663, *Propionibacterium acne*; Gram-negative: *Escherichia coli* ATCC 10536, *Salmonella typhi*, *Pseudomonas aeruginosa* ATCC 25619, *Klebsiella pneumoniae* ATCC 10031, and *Proteus vulgaris* with a minimum concentration of (2 to 2.2%) bactericidal activity (6.2 to 2%) and antifungal activity against *Epidermophyton floccosum*, *Microsporum gypseum*, *Trichophyton mentagrophytes*, *Trichophyton rubrum* ,and yeasts (*C. albicans* and *Cryptococcus neoformans*) by oil provided the minimum fungicidal concentration of 0.3% [23].

Ginger (*Z. montanum*) essential oil contains sabinene ($C_{10}H_{16}$), terpinene-4-1 (9.0-31.3%), and terpinene as the main components against eight pathogenic bacteria (Gram-positive: *S. aureus* MTCC 96, *S. epidermidis* MTCC 435 and *Streptococcus mutans* MTCC 890 were evaluated; Gram-negative: *Klebsiella pneumoniae* MTCC 109, *P. aeruginosa* MTCC 741, *E. coli* MTCC 723, *E. coli* DH5a, and *Salmonella* MTC 98 and showed good

antibacterial activity with minimum inhibitory concentration values in the range of 1025 µg/ml, indicating the lowest rate for *S. typhimurium*. The oil also showed antifungal activity (250 µg/ml) against two fungal strains (*C. albicans* ATCC 14053 and *C. albicans* MTCC 1637) [24].

3.2. *Camellia genus*

Many studies have shown the health benefits of several species of camellia, namely *C. sinensis*, *C. oleifera* and *C. japonica*. These species have antimicrobial (antibacterial, antifungal, and antiviral) and antitumor activity and are a huge source of polyphenols such as catechins. (Especially epicatechin (EC), epigallocatechin (EGC), epicatechin-3-gallate (ECG) and especially epigallocatechin-3-gallate (EGCG), the main polyphenols of green, white, and black tea [25].

Brew tea and shoot germ tea, two extracts of Turkish black tea, have been reported to be ineffective against *C. albicans*, one of the most opportunistic pathogens, as well as against other microorganisms [26]. In 2010, it was concluded that the methanolic extract of green tea leaf (*C. sinensis*) had no activity against the two species of *Aspergillus*. Both studies involved four distinct concentrations of the extract, which somewhat reinforces their conclusions [27].

The popularity of *C. sinensis* has received a great deal of attention because of its by-product, tea, which completely overshadows the remaining species of camellia, and few studies have been devoted to them. In 2013, Feás et al. studied the activity of virgin oils of *C. oleifera*, *C. reticulata* and *C. sasanqua* seeds against clinical strains of *C. albicans*. These three oils showed antifungal activity that showed different MICs [28].

3.3. *Hydnora genus*

The genus Hydnora (Hydnoraceae) is one of the basic angiosperms in the order Piperales, which is found in the semi-arid regions of Africa and the South Arabian Peninsula. As various studies have shown, plants in this genus play an essential role in communities around the world. There are currently eight species of the genus Hydnora. Seven genera are in Africa and one in *Arabian Peninsula* [29].

Hydnoraceae are grouped under the family Aristolochiaceae and include parasitic plants characterized by large, leafless flowers. They are native to the arid and semi-arid regions of Africa and Asia. Tannins have been used in local communities in Africa and the Arabian Peninsula. In Uganda, Sudan and Kenya, some species of *Hydnora* are used as food sources and to treat various ailments. *H. abyssinica* decoction is used as a medicine for inflammation, tonsillitis and dysentery in Sudan [30].

In Oman, *H. abyssinica* fruits are used as food and in leather tanning. In eastern Ethiopia, this plant (*H. abyssinica*) is used to treat diarrhea, bleeding, ulcers and oral infections. In addition, *H. abyssinica* flowers are used as wild food and in traditional medicine in South Yemen [31]. Among its therapeutic properties, antibacterial, antifungal, and antioxidant activities have been reported in *H. abyssinica* and *H. africana*. Regardless of the ethnic botanical value and medicinal importance of Hydnora, little effort has been made to integrate all relevant data [32].

4. Conclusion

Due to the prevalence and spread of fungal and bacterial diseases, the effort to find treatments has increased more than before. The application of plant compounds for treatment of fungal and bacterial diseases can be effective due to their unique biocompatible and bioavailable. All the compounds related to *Pestalotiopsis*, *Zingiber*, and *Hydnora* have shown a positive effect in killing a group of fungal and bacterial pathogens and are the suitable options instead of chemical drugs.

Conflict of Interests

The author declares no conflict of interest.

Ethics approval and consent to participate

No human or animals were used in the present research.

Consent for publications

The author read and approved the final manuscript for publication.

Availability of data and material

All the data were embedded in the manuscript.

Informed Consent

The author declares not to use any patients in this research.

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References

1. Alavi M, Rai M, Martinez F, Kahrizi D, Khan H, Rose Alencar de Menezes I, Douglas Melo Coutinho H, Costa JGM (2022) The efficiency of metal, metal oxide, and metalloid nanoparticles against cancer cells and bacterial pathogens: different mechanisms of action. Cellular, Molecular and Biomedical Reports 2(1):10-21. doi:10.55705/cmbr.2022.147090.1023
2. Alavi M, Rai M (2021) Antisense RNA, the modified CRISPR-Cas9, and metal/metal oxide nanoparticles to inactivate pathogenic bacteria. Cellular, Molecular and Biomedical Reports 1(2):52-59. doi:https://doi.org/10.55705/cmbr.2021.142436.1014
3. Abbas-Al-Khafaji ZK, Aubais-aljelehawy Qh (2021) Evaluation of antibiotic resistance and prevalence of multi-antibiotic resistant genes among Acinetobacter baumannii strains isolated from patients admitted to al-yarmouk hospital. Cellular, Molecular and Biomedical Reports 1(2):60-68. doi:https://doi.org/10.55705/cmbr.2021.142761.1015
4. Aubais aljelehawy Qh, Hadi Alshaibah LH, Abbas Al- Khafaji ZK (2021) Evaluation of virulence factors among Staphylococcus aureus strains isolated from patients with urinary tract infection in Al-Najaf Al-Ashraf teaching hospital. Cellular, Molecular and Biomedical Reports 1(2):78-87. doi:https://doi.org/10.55705/cmbr.2021.144995.1017
5. Lee Y, Puumala E, Robbins N, Cowen LE (2021) Antifungal Drug Resistance: Molecular Mechanisms in Candida albicans and Beyond. Chemical Reviews 121(6):3390-3411. doi:https://doi.org/10.1021/acs.chemrev.0c00199
6. Torres-Contreras AM, Garcia-Baeza A, Vidal-Limon HR, Balderas-Renteria I, Ramírez-Cabrera MA, Ramirez-Estrada K (2022) Plant Secondary Metabolites against Skin Photodamage: Mexican Plants, a Potential Source of UV-Radiation Protectant Molecules. Plants 11(2):220. doi:https://doi.org/10.3390/plants11020220
7. Gakuubi MM, Munusamy M, Liang Z-X, Ng SB (2021) Fungal Endophytes: A Promising Frontier for Discovery of Novel Bioactive Compounds. Journal of Fungi 7(10):786. doi:https://doi.org/10.3390/jof7100786
8. Pothiraj C, Balaji P, Shanthi R, Gobinath M, Suresh Babu R, Munirah AA-D, Ashraf AH, Ramesh Kumar K, Veeramanikandan V, Arumugam R (2021) Evaluating antimicrobial activities of Acanthus ilicifolius L. and Heliotropium curassavicum L against bacterial pathogens: an in-vitro study. Journal of Infection and Public Health 14(12):1927-1934. doi:https://doi.org/10.1016/j.jiph.2021.10.013
9. Yeshi K, Crayn D, Ritmejerytė E, Wangchuk P (2022) Plant Secondary Metabolites Produced in Response to Abiotic Stresses Has Potential Application in Pharmaceutical Product Development. Molecules 27(1):313. doi: https://doi.org/10.3390/molecules27010313
10. Yu H, Zhang L, Li L, Zheng C, Guo L, Li W, Sun P, Qin L (2010) Recent developments and future prospects of antimicrobial metabolites produced by endophytes. Microbiological Research 165(6):437-449. doi:https://doi.org/10.1016/j.micres.2009.11.009
11. Alavi M (2022) Bacteria and fungi as major bio-sources to fabricate silver nanoparticles with antibacterial activities. Expert Rev Anti-Infect Ther):1-10. doi:https://doi.org/10.1080/14787210.2022.2045194

12. Alavi M, Karimi N (2020) Hemoglobin self-assembly and antibacterial activities of bio-modified Ag-MgO nanocomposites by different concentrations of Artemisia haussknechtii and Protoparmeliopsis muralis extracts. Int J Biol Macromol 152:1174-1185. doi:https://doi.org/10.1016/j.ijbiomac.2019.10.207
13. Alavi M, Nokhodchi A (2022) Antimicrobial and wound healing activities of electrospun nanofibers based on functionalized carbohydrates and proteins. Cellulose 29(3):1331-1347. doi:https://doi.org/10.1007/s10570-021-04412-6
14. Alavi M, Hamblin MR, Martinez F, Kennedy JF, Khan H (2022) Synergistic combinations of metal, metal oxide, or metalloid nanoparticles plus antibiotics against resistant and non-resistant bacteria. Micro Nano Bio Aspects 1(1):1-9
15. Nami S, Aghebati-Maleki A, Morovati H, Aghebati-Maleki L (2019) Current antifungal drugs and immunotherapeutic approaches as promising strategies to treatment of fungal diseases. Biomedicine & Pharmacotherapy 110:857-868. doi:https://doi.org/10.1016/j.biopha.2018.12.009
16. Oliveira LVN, Wang R, Specht CA, Levitz SM (2021) Vaccines for human fungal diseases: close but still a long way to go. npj Vaccines 6(1):33. doi:https://doi.org/10.1038/s41541-021-00294-8
17. Rai N, Kumari Keshri P, Verma A, Kamble SC, Mishra P, Barik S, Kumar Singh S, Gautam V (2021) Plant associated fungal endophytes as a source of natural bioactive compounds. Mycology 12(3):139-159. doi:https://doi.org/10.1080/21501203.2020.1870579
18. Xu D, Zhang B-Y, Yang X-L (2016) Antifungal Monoterpene Derivatives from the Plant Endophytic Fungus Pestalotiopsis foedan. Chemistry & Biodiversity 13(10):1422-1425. doi:https://doi.org/10.1002/cbdv.201600114
19. Han A-R, Kim H, Piao D, Jung C-H, Seo EK (2021) Phytochemicals and Bioactivities of Zingiber cassumunar Roxb. Molecules 26(8):2377. doi:https://doi.org/10.3390/molecules26082377
20. Pansanit A, Pripdeevech P (2018) Antibacterial secondary metabolites from an endophytic fungus, Arthrinium sp. MFLUCC16-1053 isolated from Zingiber cassumunar. Mycology 9(4):264-272. doi:https://doi.org/10.1080/21501203.2018.1481154
21. Abd Rashed A, Abd Rahman AZ, Rathi DNG (2021) Essential Oils as a Potential Neuroprotective Remedy for Age-Related Neurodegenerative Diseases: A Review. Molecules 26(4):1107. doi:https://doi.org/10.3390/molecules26041107
22. Jantan Ib, Yassin MSM, Chin CB, Chen LL, Sim NL (2003) Antifungal Activity of the Essential Oils of Nine Zingiberaceae Species. Pharmaceutical Biology 41(5):392-397. doi:https://doi.org/10.1076/phbi.41.5.392.15941
23. Pithayanukul P, Tubprasert J, Wuthi-Udomlert M (2007) In Vitro antimicrobial activity of Zingiber cassumunar (Plai) oil and a 5% Plai oil gel. Phytother Res 21(2):164-169. doi:https://doi.org/10.1002/ptr.2048
24. Verma RS, Joshi N, Padalia RC, Singh VR, Goswami P, Verma SK, Iqbal H, Chanda D, Verma RK, Darokar MP, Chauhan A, Kandwal MK (2018) Chemical composition and antibacterial, antifungal, allelopathic and acetylcholinesterase inhibitory activities of cassumunar-ginger. J Sci Food Agric 98(1):321-327. doi:https://doi.org/10.1002/jsfa.8474
25. Páscoa RNMJ, Teixeira AM, Sousa C (2019) Antioxidant capacity of Camellia japonica cultivars assessed by near- and mid-infrared spectroscopy. Planta 249(4):1053-1062. doi:https://doi.org/10.1007/s00425-018-3062-z
26. Yıldırım A, Mavi A, Oktay M, Kara AA, Algur ÖF, Bilaloğlu V (2000) Comparison of Antioxidant and Antimicrobial Activities of Tilia (Tilia Argentea Desf Ex DC), Sage (Salvia Triloba L.), and Black Tea (Camellia Sinensis) Extracts. Journal of Agricultural and Food Chemistry 48(10):5030-5034. doi:https://doi.org/10.1021/jf000590k

27. Devjani C, Sunanda C (2010) Bioassay-guided isolation and identification of antibacterial and antifungal component from methanolic extract of green tea leaves (Camellia sinensis). Research Journal of Phytochemistry 4(2):78-86
28. Feás X, Estevinho LM, Salinero C, Vela P, Sainz MJ, Vázquez-Tato MP, Seijas JA (2013) Triacylglyceride, Antioxidant and Antimicrobial Features of Virgin Camellia oleifera, C. reticulata and C. sasanqua Oils. Molecules 18(4):4573-4587. doi:https://doi.org/10.3390/molecules18044573
29. Bolin JF, Lupton D, Musselman LJ (2018) Hydnora arabica (Aristolochiaceae), a new species from the Arabian Peninsula and a key to Hydnora. Phytotaxa 338(1)
30. Mkala EM, Mutungi MM, Mutinda ES, Oulo MA, Wanga VO, Mwachala G, Hu G-W (2021) Understanding the Ethnobotany, Chemistry, Pharmacology, and Distribution of Genus Hydnora (Aristolochiaceae). Plants 10(3):494. doi:https://doi.org/10.3390/plants10030494
31. Wintola OA, Afolayan AJ (2017) Chemical Constituents and Biological Activities of Essential Oils of Hydnora africana Thumb Used to Treat Associated Infections and Diseases in South Africa. Applied Sciences 7(5):443. doi:https://doi.org/10.3390/app7050443
32. Madivoli ES, Maina EG, Kairigo PK, Murigi MK, Ogilo JK, Nyangau JO, Kimani PK, Kipyegon C (2018) In vitro antioxidant and antimicrobial activity of Prunus africana (Hook. f.) Kalkman (bark extracts) and Harrisonia abyssinica Oliv. extracts (bark extracts): A comparative study. Journal of Medicinal Plants for Economic Development 2(1):1-9. doi:https://doi.org/10.4102/jomped.v2i1.39

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