Comprehensive Review of Medicinal Plants with Anti-Tuberculosis Properties

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Abstract
Tuberculosis (TB) is a severe infectious disease caused by *Mycobacterium tuberculosis* (MTB) and remains a significant global health issue. The primary challenge in eradicating TB is the development of MTB resistance to existing antibiotics and extended treatment regimens, placing a heavy burden on healthcare systems. Consequently, there is an urgent need to discover new, effective treatments with fewer side effects. Traditional medicines from offer a wealth of medicinal plants and plant-based compounds that present a promising alternative for treating various diseases. While there is substantial research on the biotherapeutic potential of natural compounds for different diseases, TB research has lagged behind. Plant-based compounds, or phytoproducts, are being explored as potential anti-mycobacterial agents that either reduce bacterial load or modulate the immune system, thereby reducing side effects. The effectiveness of these phytochemicals is being assessed through drug delivery using nanoformulations. This review highlights the importance of plant-derived anti-TB compounds and summarizes current research on medical plants with potential anti-mycobacterial activity against MTB.

Keywords: Tuberculosis, *Mycobacterium tuberculosis,* medical plants

Introduction

Tuberculosis (TB) continues to be a serious global health concern, impacting millions of individuals globally and taking many lives each year. The rise of Mycobacterium TB strains that are extensively drug-resistant (XDR) and multi-drug resistant (MDR) has made it more difficult to manage and control the infectious disease, even with the availability of traditional treatments. Effective and reasonably priced alternative therapy approaches are desperately needed in this situation. Due to their extensive history of usage in traditional medicine, medicinal plants have drawn interest as possible sources of cutting-edge anti-tuberculosis drugs [1]. The goal of this review is to present a thorough analysis of medicinal plants that have been shown to have anti-tuberculosis capabilities, emphasizing their potential contributions to the treatment of tuberculosis and the scientific data that supports these claims. In addition to looking for novel medication possibilities, the search for anti-tuberculosis activity in medicinal plants is a recognition of the large and unexplored pool of natural chemicals that may be able to supplement current treatments. Examining several plant species that have demonstrated potential in preventing the growth of Mycobacterium TB, this review will cover their bioactive components, modes of action, and the outcomes of both in vitro and in vivo investigations [2].

By synthesizing current research findings, this article seeks to bridge the gap between traditional knowledge and modern scientific inquiry, offering insights into how these plants could be integrated into contemporary TB treatment regimens. The potential for these natural remedies to mitigate the burden of tuberculosis, particularly in regions where conventional treatments are less accessible, underscores the importance of this field of study.

Tuberculosis infection and tuberculosis disease

Tuberculosis is a disease caused by *Mycobacterium tuberculosis*. Tuberculosis infection occurs when a person carries the tuberculosis bacteria in their body, but the bacteria remain dormant due to their low numbers. In this dormant state, the bacteria are controlled by the body's defense system and do not cause illness. Many people around the world have this latent infection and remain healthy. Tuberculosis disease occurs when one or more organs become infected, showing clinical signs and symptoms. This happens because the tuberculosis bacteria have started to multiply, reaching a level where they overpower the body's defenses. Similarities and differences between latent infection and TB disease: Most individuals contract TB infection by inhaling the bacteria, which the immune system then controls to keep the bacteria inactive but alive in the body. Most of these individuals never develop tuberculosis, but if their immune system becomes weakened, the bacteria can multiply and cause tuberculosis. This risk is higher in infants, children, elderly people, HIV-positive patients, drug addicts, diabetics, patients with severe kidney failure, silicosis, head and neck cancers, leukemia, Hodgkin's disease, smokers, and those taking immunosuppressive drugs. Contact with *Mycobacterium tuberculosis* can occur at any age. After contracting *Mycobacterium tuberculosis*, a person can remain in the latent stage for years or even a lifetime. Among people not infected with the HIV virus (about 90% of cases), most will never develop active tuberculosis even if exposed to *Mycobacterium tuberculosis*. In China, there may be no clinical disease, but a positive tuberculin skin test is the only indication of exposure [3]. People with *Mycobacterium tuberculosis* can develop tuberculosis at any time, and the disease can affect various tissues and organs of the body, especially the lungs. The likelihood of developing the disease is highest shortly after exposure and decreases over time. Due to an immature immune system, infants and children are at a higher risk of contracting tuberculosis, and in this age group, the possibility of tuberculosis spreading from the lungs to other parts of the body is greater. In sick children, the first year after infection is the most critical. However, not all infected children will develop tuberculosis during childhood; it may develop later in life. Physical and mental stress can trigger the development and progression of tuberculosis [4].

Drug-resistant tuberculosis

Drug-resistant tuberculosis (TB) is a serious global health issue characterized by strains of *Mycobacterium tuberculosis* that do not respond to standard first-line anti-TB medications. This resistance complicates efforts to control and eradicate TB. Drug-resistant TB is categorized into several types: Multidrug-Resistant TB (MDR-TB), which resists isoniazid and rifampicin; Extensively Drug-Resistant TB (XDR-TB), which also resists fluoroquinolones and at least one second-line injectable drug; Pre-Extensively Drug-Resistant TB (Pre-XDR-TB), which is MDR-TB with resistance to fluoroquinolones; and Rifampicin-Resistant TB (RR-TB), resistant to rifampicin alone or with other drugs. The main causes of drug resistance include incomplete or improper treatment, inadequate healthcare management, and the transmission of resistant strains between individuals. Diagnosis involves drug susceptibility testing, genetic, and phenotypic tests to identify resistance patterns. Treatment is complex, involving second-line drugs with a long duration and significant side effects. Preventive measures focus on ensuring effective treatment, infection control, and patient support. The global impact is severe, with significant cases reported and low treatment success rates, underscoring the need for increased funding, new drug development, and enhanced diagnostic and treatment strategies. Considering the crises caused by antibiotic resistance in this disease, researchers are looking for alternative treatments, including the use of medicinal plants [5, 6].

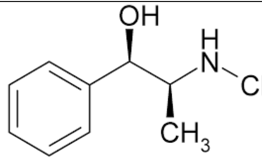
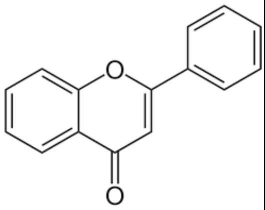
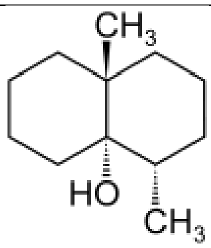
Medicinal plants and their antibacterial properties

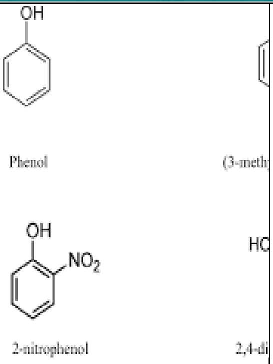
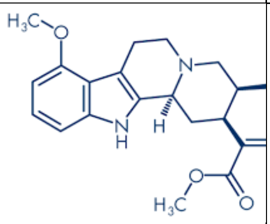
Medicinal plants are plants that have properties that can be used to prevent, treat, or manage various health conditions. These plants contain active compounds that have therapeutic effects. They can be used in various forms, such as teas, tinctures, extracts, or topical applications. Medicinal plants have been used in traditional medicine systems around the world for centuries and are also increasingly studied in modern scientific research for their potential health benefits. Medicinal plants work against bacteria in a number of ways. Certain substances derived from these plants interfere with the formation of bacterial cell walls, compromising the structural stability necessary for bacterial survival. Some disrupt the integrity of cell membranes by causing lipid bilayers to become unstable or by creating holes, which results in the loss of cell viability. Furthermore, some plant chemicals can attach to ribosomal components or enzymes to impede protein synthesis, while other compounds impact nucleic acid synthesis by targeting transcription or DNA replication processes. Plant-derived compounds also display antioxidant activity, neutralizing reactive oxygen species that can damage bacterial cells. They can inhibit critical bacterial enzymes, disrupt metabolic pathways, and deplete essential nutrients or accumulate toxic metabolites. Furthermore, some medicinal plants enhance the host's immune response, improving the body's ability to fight infections. Research continues to reveal the complexity and diversity of these mechanisms, highlighting the potential therapeutic applications of medicinal plants [7, 8].

Chemistry of natural anti-tubercular plants

Natural anti-tubercular plants have gained significant attention due to their potential to treat or complement the treatment of tuberculosis (TB), a disease caused by *Mycobacterium tuberculosis*. The chemistry of these plants often involves a range of bioactive compounds that can target various aspects of the tuberculosis infection. Table 1 represents an overview of some key plant-derived compounds and their mechanisms of action against TB:

Table 1- Chemistry of natural anti-tubercular plants

compound	Description	example	Formula	Refrences
Alkaloid	Alkaloids are a diverse group of naturally occurring organic compounds that mostly contain basic nitrogen atoms. These compounds are produced by a large variety of organisms including bacteria, fungi, plants, and animals.	Berberine, found in plants like *Berberis* species, has demonstrated anti-tubercular activity. It works by interfering with bacterial DNA synthesis and has been shown to inhibit the growth of *M. tuberculosis* in vitro. The compound may also enhance the effectiveness of conventional TB drugs.		[9]
Flavonoid	Flavonoids are a diverse group of phytonutrients (plant chemicals) found in almost all fruits and vegetables. These compounds are known for their beneficial effects on health, thanks to their antioxidant, anti-inflammatory, and anti-carcinogenic properties.	Quercetin, present in many fruits and vegetables, exhibits anti-tubercular activity by modulating the host immune response and exhibiting direct antimicrobial properties against *M. tuberculosis*. It can affect bacterial cell wall synthesis and has shown synergistic effects with standard TB drugs.		[10]
Terpenoid	Terpenoids, also known as isoprenoids, are a large and diverse class of naturally occurring organic chemicals derived from five-carbon isoprene units assembled and modified in thousands of ways. They are a significant part of the biochemistry of living organisms and have numerous industrial and medicinal applications.	Derived from *Artemisia annua*, artemisinin is well-known for its antimalarial properties, but research suggests it also has activity against *M. tuberculosis*. The mechanism is not fully understood, but it may involve the generation of reactive oxygen species that damage bacterial cells.		[11]

Phenolic Compounds	Phenolic compounds, also known as polyphenols, are a large class of chemical compounds characterized by the presence of multiple phenol units. They are widely distributed in the plant kingdom and are known for their significant role in plant growth, reproduction, and defense against pathogens and predators. Additionally, they have garnered considerable interest for their potential health benefits in humans.	Curcumin, found in turmeric (*Curcuma longa*), has anti-tubercular activity by modulating the immune system and exhibiting direct antibacterial effects. It can inhibit the growth of *M. tuberculosis* and has been shown to reduce the inflammatory response associated with TB.		[12]
Saponins	Saponins are a class of naturally occurring compounds found in a variety of plant species. They are glycosides, which means they consist of a sugar moiety (glycone) attached to a non-sugar moiety (aglycone or sapogenin). The sapogenin can be either a steroid or a triterpene.	Ginsenosides, found in ginseng (*Panax ginseng*), have shown potential in TB treatment. They act by enhancing the immune response and may also have direct antimicrobial effects against *M. tuberculosis*.		[13]

The chemistry of natural anti-tubercular plants is diverse, involving various classes of compounds with different mechanisms of action. Research into these compounds continues to uncover new insights into their potential roles in TB treatment, either as standalone therapies or as adjuncts to conventional drug regimens. Further studies are essential to fully understand their mechanisms and optimize their use in clinical settings.

Medicinal plants and their crude extracts in vitro anti-TB activity

Studies on anti-tuberculosis (TB) medicinal plants are vital due to the increasing challenge of drug-resistant TB strains like multidrug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB). These resistant strains complicate treatment with standard antibiotics, making it essential to explore alternative options such as medicinal plants, which might offer effective compounds against these strains. Additionally, pharmaceutical treatments for TB are often expensive and inaccessible, particularly in low-income regions where TB is most prevalent. Medicinal plants, being more affordable and locally available, provide a cost-effective solution, enhancing access to care in resource-limited settings. Furthermore, standard TB medications can cause severe side effects and toxicity, leading to poor patient adherence [14]. Medicinal plants might present treatments with fewer or less severe side effects, improving patient compliance and treatment outcomes. Moreover, many communities have historically used medicinal plants to treat ailments, including TB. Scientific validation of these traditional practices can preserve indigenous knowledge and integrate effective plant-based remedies into modern medicine. Plants also offer a rich source of diverse bioactive compounds, potentially leading to the discovery of novel molecules with unique mechanisms against TB. Combining conventional TB treatments with medicinal plant-based therapies could enhance treatment efficacy, reduce duration, and offer a holistic treatment strategy. Some medicinal plants may even have immune-boosting properties, contributing to preventive strategies against TB. Promoting the use of medicinal plants supports sustainable healthcare practices, encouraging the use of locally sourced plants and reducing reliance on imported pharmaceuticals, fostering self-sufficiency and sustainable health systems [15]. In the following, we will look at the results of some studies in this case and their usefulness in the fight against tuberculosis. According to a review of recent findings on the effects of anti-tuberculosis drugs, aqueous or organic solvent extracts from roots, leaves, and other parts of certain plants show promising anti-tuberculosis activity and can be used as complementary treatments for this disease (Tables 2 and 3).

Table 2- Anti-tuberculosis medicinal plants

Plant	Effect	Reference
Allium sativum	Aqueous extract was found to be 63% at 4 percent *v/v* concentration in L-J medium for sensitive *M. tuberculosis H37Rv*	[16]
Angiopteris evecta	80% methanol extract against an MIC of 400 *M. tuberculosis H37Rv ATCC 25618* with µg/ml	[17]
Citrullus colocynthis	Chloroform extracts against Mml by *MABA . tuberculosis H37Rv* with MIC of 2.5 mg/	[18]
Davilla elliptica	Chloroform extracts showed a promising antimycobacterial activity with a MIC of 62.5 µg/ml by MABA	[19]
Euphorbia hirta	Ethyl acetate extracts showed better activity with maximum of 64.73% reduction in relative light units against *M. tuberculosis H37R*	[20]
Ficus citrifolia	95% ethanol extracts against *M. tuberculosis H37Rv* (ATCC 27294) with 91% inhibition at 100 µg/ml	[21]
Gymnosperma glutinosum	Hexane extracts against *M. tuberculosis H37Ra* and H37Rv both at 31.2 µg/ml	[22]
Morinda citrifolia	Aqueous extract has an inhibition rate of 89% against *M. tuberculosis H37Rv*	[23]
Olea europaea	Hexane extracts against the drug-resistant variants of with MIC of 25-100 *µM M. tuberculosis*	[24]
Piper cernuum	Hydrodistillation with *tuberculosis H37Rv* with MIC of 125 water	[25]

	displayed moderate activity against the μg/ml M.	
Piper sarmentosum	Extracts with petroleum ether, chloroform, and methanol, against *M. tuberculosis H37Rv* with MIC of 25, 25, and 12.5 μg/ml	[26]
Rosmarinus officinalis	Ethanolic extracts *against M. tuberculosis H37Ra* with MIC of 6.25 μg/ml	[27]

Table 3- Leaf extract of anti-tuberculosis medicinal plants

Plant	Effect	Reference
Beilschmiedia obscura	Ethyl acetate extracts against *M. tuberculosis H37Rv* 31.25 μg/ml MIC	[28]
Empetrum nigrum	Hexane extracts with 95% inhibition at 100 μg/ml against *M. tuberculosis H37Rv*	[29]
Glycyrrhiza glabra	Ethanol extracts against *M. tuberculosis H37Rv* (ATCC 27294) with MIC of 250 µg/ml	[30]
Maerua edulis	Hexane extracts against *M. bovis BCG, M. tuberculosis H37Ra* with MIC 31.2–62.5 μg/ml	[31]
Rhynchosia precatoria	Extracts by n-hexane, dichloromethane, ethyl acetate, and methanol *M. tuberculosis H37Rv* with MIC of 15.6-125 μg/ml	[32]
Zingiber officinale	Ethanol extract against M. *tuberculosis H37Ra* with MIC of 2500 μg/ml	[33]

Challenges of using anti-tuberculosis medicinal plants

There are a number of major obstacles when using medicinal plants that are anti-tuberculosis (TB). The calculation of consistent doses can be complicated by factors such as species differences, growing circumstances, and post-harvest processing, which can vary the concentration of active chemicals in plants. These concerns can affect standardization and quality control. The paucity of rigorous clinical trials to verify the safety and efficacy of numerous plants, as well as the lack of clarity surrounding the processes behind their anti-TB actions, pose challenges to scientific validation. Concerns exist over toxicity and drug interactions as well, since medicinal plants may contain toxic chemicals at greater doses or may interact negatively with traditional TB medications. Another layer of complexity is created by regulatory and legal issues, which present major hurdles due to strict approval and quality control requirements. In addition, sustainability and conservation are essential since rising demand may result in overharvesting and environmental damage. Careful evaluation of interactions and complete treatment regimens are necessary when integrating medicinal plants with traditional TB treatments. Healthcare providers also need to be educated and trained in this regard. Given the high expenses of developing standardized herbal medications and restricted availability in some areas, economic and accessibility issues also come up. Funding issues and the requirement for interdisciplinary cooperation between physicians, pharmacologists, and botanists confront research and development. To ensure the safe and efficient use of medicinal plants in the treatment of tuberculosis, addressing these complex issues requires a multidisciplinary strategy that includes thorough scientific research, sustainable practices, strong regulatory frameworks, and widespread education [34].

Conclusions

According to the thorough analysis, medicinal herbs have a lot of potential as anti-tuberculosis agents and might be used in addition to current TB treatments. These plants' bioactive chemicals have a variety of effective methods against *Mycobacterium tuberculosis*, offering a potential remedy for the problems caused by drug-resistant TB strains. However, a number of obstacles must be addressed before medicinal plants may be successfully included into normal TB treatment plans. These obstacles include standardization, clinical validation, safety concerns, regulatory permissions, and sustainability. Sufficient interdisciplinary research, robust regulatory frameworks, and sustainable practices are essential for optimizing the therapeutic potential of natural therapies and possibly mitigating the worldwide tuberculosis epidemic.

References

[1] Saravanan, M., Niguse, S., Abdulkader, M., Tsegay, E., Hailekiros, H., Gebrekidan, A., ... & Pugazhendhi, A. (2018). Review on emergence of drug-resistant tuberculosis (MDR & XDR-TB) and its molecular diagnosis in Ethiopia. Microbial Pathogenesis, 117, 237-242. https://doi.org/ 10.1016/j.micpath.2018.02.047

[2] Sau, S., & Kalia, N. P. (2023). Perspectives on Anti-Tuberculosis Drug Discovery. In Drugs and a Methodological Compendium: From bench to bedside (pp. 357-375). Singapore: Springer Nature Singapore. https://doi.org/ 10.1016/j.ijmyco.2015.05.004

[3] Alonzi, T., Repele, F., & Goletti, D. (2023). Research tests for the diagnosis of tuberculosis infection. Expert Review of Molecular Diagnostics, 23(9), 783-795. https://doi.org/ 10.1080/14737159.2023.2240230

[4] Agbota, G., Bonnet, M., & Lienhardt, C. (2023). Management of tuberculosis infection: current situation, recent developments and operational challenges. Pathogens, 12(3), 362. https://doi.org/

[5] Khawbung, J. L., Nath, D., & Chakraborty, S. (2021). Drug resistant Tuberculosis: A review. Comparative immunology, microbiology and infectious diseases, 74, 101574. https://doi.org/10.3390/pathogens12030362

[6] Salari, N., Kanjoori, A. H., Hosseinian-Far, A., Hasheminezhad, R., Mansouri, K., & Mohammadi, M. (2023). Global prevalence of drug-resistant tuberculosis: a systematic review and meta-analysis. Infectious Diseases of Poverty, 12(1), 57. https://doi.org/10.1186/s40249-023-01107-x

[7] Abate, L., Bachheti, A., Bachheti, R. K., & Husen, A. (2021). Antibacterial properties of medicinal plants: recent trends, progress, and challenges. Traditional herbal therapy for the human immune system, 13-54. https://doi.org/10.1201/9781003137955-2

[8] Abdallah, E. M., Alhatlani, B. Y., de Paula Menezes, R., & Martins, C. H. G. (2023). Back to Nature: Medicinal plants as promising sources for antibacterial drugs in the post-antibiotic era. Plants, 12(17), 3077. https://doi.org/10.3390/plants12173077

[9] Ozturk, M., Chia, J. E., Hazra, R., Saqib, M., Maine, R. A., Guler, R., ... & Parihar, S. P. (2021). Evaluation of Berberine as an Adjunct to TB Treatment. Frontiers in Immunology, 12, 656419. https://doi.org/ 10.3389/fimmu.2021.656419
[10] Sasikumar, K., Ghosh, A. R., & Dusthackeer, A. (2018). Antimycobacterial potentials of quercetin and rutin against *Mycobacterium tuberculosis* H37Rv. 3 Biotech, 8, 1-6. https://doi.org/ 10.1007/s13205-018-1450-5
[11] Martini, M. C., Zhang, T., Williams, J. T., Abramovitch, R. B., Weathers, P. J., & Shell, S. S. (2020). Artemisia annua and Artemisia afra extracts exhibit strong bactericidal activity against *Mycobacterium tuberculosis*. Journal of ethnopharmacology, 262, 113191. https://doi.org/ 10.1016/j.jep.2020.113191
[12] Barua, N., & Buragohain, A. K. (2021). Therapeutic potential of curcumin as an antimycobacterial agent. Biomolecules, 11(9), 1278. https://doi.org/10.1016/j.jep.2020.113191
[13] Wang, L., Huang, Y., Yin, G., Wang, J., Wang, P., Chen, Z. Y., ... & Ren, G. (2020). Antimicrobial activities of Asian ginseng, American ginseng, and notoginseng. Phytotherapy Research, 34(6), 1226-1236. https://doi.org/10.1002/ptr.6605
[14] Oloya, B., Namukobe, J., Ssengooba, W., Afayoa, M., & Byamukama, R. (2022). Phytochemical screening, antimycobacterial activity and acute toxicity of crude extracts of selected medicinal plant species used locally in the treatment of tuberculosis in Uganda. Tropical medicine and health, 50(1), 16. https://doi.org/10.1186/s41182-022-00406-7
[15] Koirala, N., Modi, B., Subba, R. K., Panthi, M., & Xiao, J. (2021). Medicinal Plants in Targeting Tuberculosis II. Medicinal Plants for Lung Diseases: A Pharmacological and Immunological Perspective, 185-215. https://doi.org/10.1007/978-981-33-6850-7_8
[16] Gupta, R., Thakur, B., Singh, P., Singh, H. B., Sharma, V. D., Katoch, V. M., & Chauhan, S. V. S. (2010). Anti-tuberculosis activity of selected medicinal plants against multi-drug resistant *Mycobacterium tuberculosis* isolates. Indian Journal of Medical Research, 131(6), 809-813. PMID: 20571171
[17] Mohamad, S., Zin, N. M., Wahab, H. A., Ibrahim, P., Sulaiman, S. F., Zahariluddin, A. S. M., & Noor, S. S. M. (2011). Antituberculosis potential of some ethnobotanically selected Malaysian plants. Journal of ethnopharmacology, 133(3), 1021-1026. https://doi.org/ 10.1016/j.jep.2010.11.037
[18] Ullah, S., Hussain, S., Khan, S. N., Khurram, M., Khan, I., & Khan, M. A. (2017). The medicinal plants in the control of tuberculosis: Laboratory study on medicinal plants from the Northern Area of Pakistan. The International Journal of Mycobacteriology, 6(1), 102-105. https://doi.org/10.4103/ijmy.ijmy_11_17
[19] Lopes, F. C. M., Placeres, M. C. P., Jordão Junior, C. M., Higuchi, C. T., Rinaldo, D., Vilegas, W., ... & Carlos, I. Z. (2007). Immunological and microbiological activity of Davilla elliptica St. Hill.(Dilleniaceae) against *Mycobacterium tuberculosis*. Memórias do Instituto Oswaldo Cruz, 102, 769-772. https://doi.org/10.1590/S0074-02762007005000086
[20] Rajasekar, T., Anbarasu, S., Manikkam, R., Joseph, J., & Kumar, V. (2015). Inhibitory activity of Euphorbia hirta (Tawa-tawa) extracts against *Mycobacterium tuberculosis* and other non mycobacterial pathogens. Der Pharma Chemica, 7(8), 213-216. https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/8291360
[21] Antoun, M. D., Ramos, Z., Vazques, J., Oquendo, I., Proctor, G. R., Gerena, L., & Franzblau, S. G. (2001). Evaluation of the flora of Puerto Rico for in vitro antiplasmodial and antimycobacterial activities. Phytotherapy Research: PTR, 15(7), 638-642. https://doi.org/10.1002/ptr.880

[22] Gomez-Flores, R., Arzate-Quintana, C., Quintanilla-Licea, R., Tamez-Guerra, P., Tamez-Guerra, R., Monreal-Cuevas, E., & Rodríguez-Padilla, C. (2008). Antimicrobial activity of Persea americana Mill (Lauraceae)(Avocado) and Gymnosperma glutinosum (Spreng.) Less (Asteraceae) leaf extracts and active fractions against *Mycobacterium tuberculosis*. American-Eurasian Journal of Scientific Research, 3(2), 188-194. https://doi.org/10.21010/ajtcam.v13i4.9

[23] Pan, S. Y., Zhou, S. F., Gao, S. H., Yu, Z. L., Zhang, S. F., Tang, M. K., ... & Ko, K. M. (2013). New perspectives on how to discover drugs from herbal medicines: CAM′ S outstanding contribution to modern therapeutics. Evidence-Based Complementary and Alternative Medicine, 2013(1), 627375. https://doi.org/10.1155/2013/627375

[24] Camacho-Corona, M. D. R., Ramírez-Cabrera, M. A., Santiago, O. G., Garza-González, E., Palacios, I. D. P., & Luna-Herrera, J. (2008). Activity against drug resistant-tuberculosis strains of plants used in Mexican traditional medicine to treat tuberculosis and other respiratory diseases. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 22(1), 82-85. https://doi.org/10.1002/ptr.2269

[25] Bernuci, K. Z., Iwanaga, C. C., Fernandez-Andrade, C. M. M., Lorenzetti, F. B., Torres-Santos, E. C., Faioes, V. D. S., ... & Cortez, D. A. G. (2016). Evaluation of chemical composition and antileishmanial and antituberculosis activities of essential oils of Piper species. Molecules, 21(12), 1698. https://doi.org/10.3390/molecules21121698

[26] Hussain, K., Ismail, Z., Sadikun, A., & Ibrahim, P. (2008). Analysis of proteins, polysaccharides, glycosaponins contents of Piper sarmentosum Roxb. and anti-TB evaluation for bio-enhancing/interaction effects of leaf extracts with Isoniazid (INH). Natural Product Radiance 7(5):402-408. Corpus ID: 13874514

[27] Abuzeid, N., Kalsum, S., Koshy, R. J., Larsson, M., Glader, M., Andersson, H., ... & Lerm, M. (2014). Antimycobacterial activity of selected medicinal plants traditionally used in Sudan to treat infectious diseases. Journal of Ethnopharmacology, 157, 134-139. https://doi.org/10.1016/j.jep.2014.09.020

[28] Nkenfou, C. N., Mawabo, I. K., Notedji, A., Nkenfou, J., Fokou, P. V. T., Jouda, J. B., & Kuiate, J. R. (2015). In vitro antimycobacterial activity of six Cameroonian medicinal plants using microplate alamarBlue assay. The International Journal of Mycobacteriology, 4(4), 306-311. https://doi.org/10.1016/j.ijmyco.2015.08.004

[29] Gordien, A. Y., Gray, A. I., Ingleby, K., Franzblau, S. G., & Seidel, V. (2010). Activity of Scottish plant, lichen and fungal endophyte extracts against *Mycobacterium aurum* and *Mycobacterium tuberculosis*. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 24(5), 692-698. https://doi.org/10.1002/ptr.2988

[30] Gupta, V. K., Fatima, A., Faridi, U., Negi, A. S., Shanker, K., Kumar, J. K., ... & Khanuja, S. P. (2008). Antimicrobial potential of Glycyrrhiza glabra roots. Journal of ethnopharmacology, 116(2), 377-380. https://doi.org/10.1016/j.jep.2007.11.037

[31] Luo, X., Pires, D., Aínsa, J. A., Gracia, B., Mulhovo, S., Duarte, A., ... & Ferreira, M. J. U. (2011). Antimycobacterial evaluation and preliminary phytochemical investigation of selected medicinal plants traditionally used in Mozambique. Journal of Ethnopharmacology, 137(1), 114-120. https://doi.org/10.1016/j.jep.2011.04.062

[32] Coronado-Aceves, E. W., Sánchez-Escalante, J. J., López-Cervantes, J., Robles-Zepeda, R. E., Velázquez, C., Sánchez-Machado, D. I., & Garibay-Escobar, A. (2016). Antimycobacterial

activity of medicinal plants used by the Mayo people of Sonora, Mexico. Journal of Ethnopharmacology, 190, 106-115. https://doi.org/10.1016/j.jep.2016.05.064

[33] Nguta, J. M., Appiah-Opong, R., Nyarko, A. K., Yeboah-Manu, D., Addo, P. G., Otchere, I., & Kissi-Twum, A. (2016). Antimycobacterial and cytotoxic activity of selected medicinal plant extracts. Journal of ethnopharmacology, 182, 10-15. https://doi.org/10.1016/j.jep.2016.02.010

[34] Sivakumar, A., & Jayaraman, G. (2011). Anti-tuberculosis activity of commonly used medicinal plants of south India. J Med Plants Res, 5(31), 6881-6884. https://doi.org/10.5897/JMPR11.1397