Introduction

Tuberculosis (TB), which has been and still remains a serious disease to the global human population causing millions of deaths worldwide. The recent increase in the number of multi-drug resistant clinical isolates of *Mycobacterium tuberculosis* has created an urgent need for the discovery and development of new antituberculosis drugs. Medicinal plants have had a great influence on the daily lives of people living in developing countries, particularly in Africa, as the population in these countries cannot generally afford the cost of Western medicines.

In Ethiopia, the acetone fraction obtained from the stem bark of *Combretum molle* (Combretaceae) showed significant inhibitory activity against *Mycobacterium tuberculosis* strain. The acetone fraction of the stem bark of *C. molle* caused complete inhibition at concentrations higher than 1 mg/mL. Phytochemical analysis of the bioactive fraction led to the isolation of a major tannin and two oleanane-type pentacyclic triterpene glycosides. The tannin was identified as the ellagitannin, punicalagin, whilst the saponins were characterized as arjunglucoside (also called 4-epi-sericoside) and sericoside. All the pure compounds were further tested against the *M. tuberculosis* ATCC strain. Punicalagin was found to inhibit totally growth of the ATCC and also of a patient strain, which was fully sensitive to the standard antituberculosis drugs, at concentrations higher than 600 μg/mL and 1.2 mg/mL, respectively.

Also, in Eastern Cape, South Africa has been assayed antitubercular activity of polyherbal formulations with several medicinal plants active to concentrations between 25-50 μg/mL [1].

In addition, essential oils have been derived from *S. aratocensis, T. diffusa* and *L. americana*, three aromatic plants of Colombia that are active against tuberculosis.

Emergence of new drug resistant variants

A number of antimicrobial agents already exist for various purposes but the search for new antimicrobial agents should be a continuous one since the target microorganisms often evolve into new genetic variants which subsequently become resistant to existing agents [2].

The current first line drugs for TB (isoniazid, rifampicin, pyrazinamide and ethambutol) were discovered decades ago and are becoming less effective due to the emergence of drug resistance and the counteractions of HIV infection. Furthermore, effective use of these drugs require months of combination therapy, leading to issues with compliance and significant side effects. Thus, there is an urgent need to discover new TB drugs.
Better and safer drug regimens to shorten treatment is vital in attaining the WHO’s ambitious targets of 95% reduction in TB deaths and 90% reduction in TB incidence by 2035 [3].

Natural products of plant biodiversity have received considerable attention as potential anti-TB agents since they are a proven template for the development of new molecules against tuberculosis. Many antitubercular compounds that may prove to be useful leads for TB drug discovery have been derived from medicinal plants [4,5].

Natural product drug discovery works on the basis that biological diversity is the key to chemical diversity [6]. One prerequisite for the discovery of novel bioactive compounds is choosing suitable source material which significantly increases the chance of “hitting a target”. Plants have long been viewed as a common source of remedies, either in the form of traditional preparations or as pure active principles. This forms a strong basis to utilize local plants that have been traditionally used as medicine and investigate them for their active chemical constituents [7–10].

New tuberculosis drug targets

Some selective targets essential to the survival of the microorganism considered in the development of any anti-TB drug include the cell wall which provides protection to the Mycobacteria and is impermeable to a number of drugs, while also conferring inherent resistance [11]. In this way, natural terpenes have the ability of produce microbial cell wall disruption causing lysis [12]. Amino acid and co-factor biosynthesis; targeting the amino acid synthesis and co-factor pathways in the bacteria causes reduced metabolism and reproductive activity in the organisms [13], and DNA metabolism; ribonucleotide reductases are essential to the Mycobacterium and reproduction activities. Equally antibiofilm activity using Mycobacterium smegmatis 155 mcrc is a important model for antitubercular activity because biofilms provides a niche for establish antimicrobial resistance [14,15].

Selected natural products with Anti-TB prospects

Antimycobacterial bioactive chemical molecules have been found from many natural product skeletons, mainly from plant biodiversity, but also from other organisms, such as fungi and marine organisms. Because natural products are a proven template for the development of new scaffolds of drugs, they have received considerable attention as potential anti-TB agents. A wide range of phytoconstituents are responsible for anti-tubercular activity includes alkaloids, glycosides, tannins, phenolics, xanthones, quinones, sterols, triterpenoids etc. These phytoconstituents present in plant exert desired pharmacological effect on body and thus act as natural anti-tubercular agents. Constituents from Medicinal plants play a key role in drug discovery programs, both serving as drugs and as templates for the synthesis of new drugs. This review summarizes the correlation between the uses of plants in Traditional African medicine against Tuberculosis (TB) and the biological activities of the derived natural products (both extracts and isolated compounds), with the aim to validate the use of traditional medicine against TB in African countries. The study was done by curating data from journals in natural products and phytomedicine. It was observed that the ethnobotanical uses of the plant species surveyed correlated with the bioactivities of the plant extracts and isolated compounds identified. In addition in drug–extract combination assays has been possible to determine synergistic activity of combinations of antimycobacterial drugs with medicinal plants, opening the horizon of new impact studies on traditional medicine uses [16].

Socio-economic need of Anti-Tb natural products

Natural products especially plants have played a significant socio-economic role by fulfilling health–care needs and creating business opportunities for the less privileged population of the developing world [17].

Tuberculosis (TB) is the most ancient epidemic disease in the world and a serious opportunistic disease in HIV/AIDS patients. The increase in multidrug resistant Mycobacterium tuberculosis (MDR–TB, XDR–TB) demands the search for novel antimycobacterial drugs.

In the past centuries, a majority of the local population in Africa, India, and China have depended on medicinal plants as their main source of treatment of medical disorders and ailments [18]. Therefore, several plant species have been used traditionally to treat various diseases/ailments. Traditional medicine has been defined by the World Health Organization (WHO) as practices, knowledge and belief systems which use minerals, plants and animal based remedies, spiritual therapies and exercises to prevent, treat and maintain well-being [19]. The statement that natural products represent an enormous potential for drugs leads cannot be disputed [20]. This is because natural products often result from an optimized evolutionary process in which chemicals have been under the selective forces of coevolution, organisms producing substances (secondary metabolites) in the presence of their predators for their own defence mechanism and survival.

These natural compounds (secondary metabolites) have been utilized and chemically modified by humans since ancient times to treat and cure their diseases [21]. A quick search of the literature (the main stream natural products journals and PhD theses from university libraries) could give an estimate of >10000 unique compounds which have been previously isolated from natural products (flora, algae and fauna). A lot of these medicinal plants have been widely used in Africa.

Also, is important to validate the ethnopharmacological uses of biodiversity, with the end to promote the proper use of plants and find new sources of medicines. This approach is necessary especially in the countries with tuberculosis high burden [22].

Evaluation of the bioactive natural products

In many countries especially in subSaharan Africa, ethnobotanical and ethnomedical knowledge have been greatly exploited to evaluate the antimycobacterial properties of plants in vitro using crude extracts [23,24]. Some crude extracts...
have shown remarkable antimycobacterial activities against Mycobacterium tuberculosis and other mycobacteria [25].

This review therefore represent a continuation of the survey of the search for anti-tuberculosis agents from African flora. This is backed by correlating the biological activities of the isolated metabolites with the ethnobotanical uses of the plant species.

The most used methods in antitubercular in vitro drug discovery have been described as agar dilution, broth dilution, MGIT 960 fluorescence assay, microplate alamar blue assay (MABA), resazaurin microtiter assay (REMA) and tetrazolium microplate assay [26,27, 28]. Also, MBEC™ assay system (MBEC™ Biofilm Technologies Ltd. Calgary, AB, Canada) has been employed for to evaluate antibiofilm activity of new drugs so it can be very useful to complement antimicrobial assays of natural products from medicinal plants [29].

**Outcome of evaluated bioactive compounds**

Interesting results for classes of compounds which exhibit antituberculosis biological activities correlating with the ethnobotanical uses of the plant species of origin have been widely obtained.

*Tabernaemontana elegans* (toad tree) is an alkaloid which has been reported to be used traditionally by the Venda and Zulu people of South Africa: a root decoction is applied as a wash to wounds, and drunk for pulmonary diseases and chest pains [30]. It has been previously reported that extracts of this plant have demonstrated antibacterial activity against *S. aureus* and antymycobacterial activity against *M. smegmatis* [31].

*Lippia javanica* (*Verbenaceae*) is an aromatic herb that occurs all over Mozambique. Infusions of its leaves is commonly used in Africa as tea against various ailments like influenza, measles, rashes, malaria, stomach problems, fever, colds, cough, headaches [32] and isolated triterpene euscaphic acid from this plant [33]. This compound was tested against *Mycobacterium tuberculosis*, it was found to exhibit a minimum inhibitory concentration of 50 μg/mL against sensitive strain of *M. tuberculosis*, H37Rv, reference strain (27294).

The plant species *A. afrà* (commonly called African wormwood) is widely distributed in South Africa from the Cederberg Mountains in the Cape, northwards to tropical East Africa [34]. This plant is reported to be used to treat coughs, colds, diabetes, malaria, sore throat, asthma, headache, dental care, gout and intestinal worms in South Africa [35]. In vitro studies of *A. afrà* extracts have revealed that the plant is a potential antidepressant, cardiovascular, spasmyloytic effects, antioxidiant, and antymycobacterial [36].

The roots of *Euclea natalensis* (*Ebenaceae*) are used to relief toothache, headache and chest complaints amongst other uses [37]. The compounds shinanolone, 7-methyljuglone and diospyrin isolated from this plant [38] are used to relief toothache, headache and chest complaints amongst other uses. The three napthoquinones; shinanolone, 7-methyljuglone and diospyrin demonstrated significant activity against drug sensitive and drug–resistant strains of *Mycobacterium tuberculosis* and lends credence to the ethnomedicinal use of the plant [39].

*Knowltonia vesicatoria* (*Ranunculaceae*) is a South African plant traditionally used to treat tuberculosis. Extracts of this plant is used in combination with isoniazid (INH) to investigate the possibility of synergy with respect to antmycobacterial activity. The compounds 5-((hydroxymethyl) furan–2(5H)–one and 5–(hydroxymethyl) dihydrofuran–2(3H)–one were isolated from this plant and demonstrated antymycobacterial activity.

The activity validates the traditional use of the plant in the treatment of tuberculosis. Many bioactive compounds was active against drug sensitive *M. tuberculosis* with an MIC of 50.0 mg/mL [40].

*Bolusanthus speciosus* (*Fabaceae*) is a common plant that is widely distributed in subtropical South Africa, Botswana, Zimbabwe, Mozambique and Zambia. The dried inner bark of the tree is used traditionally to relieve abdominal pains, emetism and tuberculosis [41]. Two new isoflavonoids 4,7,2′-trihydroxy-4′-methoxyisoflavanol and 5,7,3′,4′-tetrahydroxy-5′-(2-epoxy-3-methylbutyl) isoflavonone isolated from the stem bark this plant were tested for antimicrobial activity [42].

Many other bioactive compounds demonstrated moderate activity against gram positive and gram negative bacteria. The results seem to support the traditional use of the plant in treatment of microbial infections.

Lall et al. [43], reported the antiviral and antitubercular activity of *Helichrysum melanacme* by carrying out bioassay guided fractionation of the acetonic extract of this plant. *Helichrysum melanacme* (*Asteraceae*) is a widely used medicinal plant in Southern Africa to treat cough, fever, headache, colds and chest pain. The plant extracts, and isolated compounds 2,4′,6′-trihydroxy-3′-prenylchalcone and 4′,6′,5′-trihydroxy-6′-6″-dimethyldihydropyranone [2″,3″-,2′,3′] chalcone were active against *M. tuberculosis* with MICs of 0.5 and 0.05 mg/mL, respectively [44], *Leonotis leonurus*, commonly called Wild dagga or Lion’s ear, is a robust perennial shrub which is widespread throughout eastern South Africa, growing amongst rocks in grassland [45]. The plant has found a wide variety of medicinal applications in treating colds, bronchitis, tuberculosis, coughs, asthma, feverish headaches, and dysentery and chest infections [30]. It was identified as a potential source of novel anti–tuberculosis compounds.

The organic extracts of this plant showed greater than 99% growth inhibition against *Mycobacterium tuberculosis* when tested at 1000 mg/ml with rifampcin as the positive control (2 mg/ml), and was considered to have potent activity against *Mycobacterium tuberculosis* [46], which correlate to it application in traditional use.

Green et al. carried out a study in which some selected medicinal plants were collected and their inhibitory properties against *Mycobacterium tuberculosis* was evaluated [47]. The acetone extracts of *Bridelia micrantha*, *Terminalia sericea*,...
and Warbugia salutaris showed a MIC of 25μg/mL against the two tested MTBs trains. The acetone extracts of Berchemia discolor demonstrated the highest antimycobacterial activity with MIC of 12.5μg/mL [48]. Prenylated flavonoid [49], and other secondary metabolites including friedelin, epifriedelin and phenolic derivatives such as gallic acid, ellagic acids, anthocyanidin, taraxerol, taraxerone and caffeic acid have been isolated from these plants species [50]. And generally, flavonoids are known for their antituberculosis properties [51]. Ziziphus mucronatha, Scotia brakepetale, Rhus rogersii, Securidaca longipedunculata, Peltophorum africanum, Cassia petersiana, Scherocarya birrea, Rhoicissus tridentate, Grewia villosa, Piper capense and Carissa edulis presented lower but interesting activities with MIC between 50 and 100μg/mL [52].

According to Ngemenya et al. [53], some drugs do show potent activity in vivo due to metabolic transformation of their components into highly active intermediates, so can some of these plants species [50]. And generally, flavonoids are known for their antituberculosis properties [51]. Ziziphus mucronatha, Scotia brakepetale, Rhus rogersii, Securidaca longipedunculata, Peltophorum africanum, Cassia petersiana, Scherocarya birrea, Rhoicissus tridentate, Grewia villosa, Piper capense and Carissa edulis presented lower but interesting activities with MIC between 50 and 100μg/mL [52].

Challenges of developing Anti-Tb drug from plants

The classic pathway towards anti-TB drug discovery from natural products and other infectious diseases must overcome a number of challenges.

The first is to reliably detect efficacious and safe hits and be able to identify already known compounds at the early stages of the drug discovery program.

The second major challenge is the de novo structure elucidation of new molecular entities. Though current advances in spectroscopic techniques, specifically the high resolution neutron magnetic resonance (NMR) technologies have been contributed to the resolution of this challenge. Many approaches have been developed to solve the major hurdle, but it still remains a major challenge in anti-TB drug discovery from natural products [55]. Innovative technology is needed to impact the early phases of anti-TB drug discovery from natural products, innovative technologies need to be leveraged for

---

**Table 1: Compounds that exhibit biological activities correlating with the ethnomedicinal uses of the plant species of origin.**

| Plant Species                     | Phytochemical constituents                                      | Reported pharmacological activity                                                                 | References |
|-----------------------------------|----------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|------------|
| Azadirachta indica A. Juss.       | Flavonoids, tannins                                             | Activity against K. pneumoniae, M. smegmatis and M. aurum                                           | [39]       |
| Chenopodium ambrosioides L.       | Phenolics, flavonoids, saponins, ecydysteroids and triterpenoids| Activity against MDR strains of M. tuberculosis                                                    | [40]       |
| Solanum torvum Sw (fruits and leaves) | Sterols, tannins, saponins, flavonoids, glycosides         | Activity against M. tuberculosis H37Rv                                                             | [41]       |
| Bidens pilosa L                   | Chalcone glucosides                                            | Activity against drug sensitive M. tuberculosis                                                    | [42]       |
| Allium sativum                    | Alkaloids, flavonoids, cardiac glycosides, terpenes, resin     | Active against M. tuberculosis MDR strains and H37Rv                                              | [44]       |
| Allium cepa (bulb and leaves)     | Alkaloids, flavonoids, cardiac glycosides, terpenes, resin     | Active against M. tuberculosis MDR strains and H37Rv                                              | [45]       |
| Aloe vera var. barbadensis (aqueous and organic extracts) | Tannins, saponins, flavonoids, terpenoids | Activity against M. tuberculosis MDR strains and H37Rv                                           | [46]       |
| Acalypha indica, (leaves)         | Kaempferol, Acalyphamide quinone, sterols, cyanogonic glycoside | Activity against M. avium                                                                     | [47]       |
| Allium cepa (bulbs)               | Allicin, flavonoids; phenolic acids and sterols                | Activity against Mycobacterium tuberculosis                                                    | [49]       |
| Vitex trifolia                    | Flavonoids-arnetin, luteolin, orientin, casticin; and iridoid glycosides | Activity against M. smegmatis                                                               | [48]       |
| Zanthoxylum capense (roots)       | Benzopanthenidine, decarine, 6- acetonyldyhydronitidine, N-isobutyl-(2E,4E)-2,4-tetradecadienamide | Activity against M. tuberculosis                                                              | [50]       |
| Trichosanthes dioica (stem and leaves) | Berberine, columbin, chasmanthin, palmarin, inosporon, tinosporic acid and tinosporol | Activity against drug sensitive M. tuberculosis                                                | [51]       |
| Ocimum sanctum (leaves and seeds) | Ursolic acid, apigenin, orientin, luteolin                      | Activity against M. tuberculosis H37Rv                                                          | [52]       |
| Garcinia nobilis (Stem bark)      | Smeanthoxanthine, 8-hydroxycuraxanthone, morisignin, 4-prenyl-2-(3,7-dimethyl-2-octadienyl)-1,3,5,8-tetrahydroxanthone | Activity against M. tuberculosis H37Rv                                                       | [54]       |
| Ficus chlamydocarpa (stem bark)   | Alpinusinosolfavone, genistein, laburnetin and luteolin         | Activity against drug resistant M. tuberculosis                                                    | [55]       |
| Citrullus colosnthis (deseeded fruits) | Ursolic acid, cucurbiticat E and cucurbiticin l  | Activity against M. tuberculosis H37Rv                                                          | [56]       |
| Morinda citrifolia, (leaves, roots and fruits) | Anthraquinonesalizarin, nordamnacanthol, Ursolic acid; β-Sitosterol, asperulose and caproic acid | Activity against drug sensitive M. tuberculosis                                                  | [57]       |
| Terminalia avicennioides (Root bark) | Arjunolic acid, friedelin and friedelin-3β-ol     | Activity against drug sensitive M. tuberculosis                                                  | [58]       |
| Orica suaveolens (stem bark)      | Evoxanthine and 1-hydroxy-2,3-dimethoxy-10- methylacridione     | Activity against drug sensitive M. tuberculosis                                                  | [59]       |
| Andrographis paniculata (Leaves)  | Andrographolide                                                 | Activity against drug sensitive M. tuberculosis                                                  | [60]       |
Table 2: Biological activity of some derived natural products versus ethnobotanical uses of plant species derived from African flora.

| Plant species             | Family            | Isolated metabolite                                                                 | Ethnobotanical use                                                                 | Measured activity                  | Reference |
|---------------------------|-------------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------|-----------|
| Tabernaemontan elegans    | Apocynaceae       | Voacangine and dregamine                                                            | Applied as a wash to wounds, and drunk for pulmonary diseases and chest pains      | Antimicrobial activity              | [61]      |
| Artemisia afra            | Asteraceae        | α-Myrin and betulinic acid                                                           | Used to treat coughs, colds, diabetes, malaria, sore throat, asthma, headache,    | Antimicrobial activity              | [43]      |
| Euclia natalensis         | Ebenaceae         | Shinanolone, 7-methyljugalone and diospyrin                                         | Used to relief toothache, headache and chest complaints.                           | Antimycobacterial activity         | [62]      |
| Lippia javanica           | Verbenaceae       | Euscaphic acid, (E)-2(3) Tagetone epoxide, myrcenone, piperitenone or 3-methyl-6-(1 methylthylidene)-cyclohex-2-en-1-one | Infusion is commonly used in Africa as a tea against various ailments like influenza, measles, rashes, malaria, stomach problems, fever, colds, cough, headaches | Antimycobacterial and antimicrobial activity | [63,64] |

Knowltonia vesicatoria    | Ranunculaceae     | 5-(hydroxymethyl) furan-2(5H)-one and 5-(hydroxymethyl) dihydrofuran-2(3H)-one     | Used traditionally to treat tuberculosis                                             | Antimycobacterial activity         | [65]      |
| Bolusanthus speciosus     | Fabaceae          | 4,7,2'-trihydroxy-4'-methoxyisoflavanone and 5,7,3',4'-tetrahydroxy-5'(2-epoxy-3- methylbutyl) isoflavonone | Dried inner bark of the tree is used traditionally to relieve abdominal pains,     | Antimicrobial activity              | [66]      |
| Helichrysum melanacme     | Asteraceae        | 2',4',6'-trihydroxy-3'-prenylchalcone and 4',6,5'-trihydroxy-4',6'-dimethylidihydropyrano [2',3'-2,3'] chalcone | Used to treat cough, fever, headache, colds and chest pain                         | [67]      |
| Leonotis leonurus         | Lamiaceae         | 9,13-Epoxy-6-hydroxy-16,15-labdanolide and 9,13,15,16-diepoxo-6,16- labdanediol      | Treating colds, bronchitis, tuberculosis, coughs, asthma, feverish headaches,    | Antimycobacteria                   | [53,68]  |
| Bridelia micrantha        | Euphorbiaceae     | friedelin, epifriedelin, gallic acid, ellagic acids, anthocyanidin, taraxerol, taraxerone and caffeic acid. | For treatment of stomach aches, tapeworms, diarrhoea, headaches, sore joints,     | [69,70]   |
| Piper capense             | Piperaceae        | Used for cough, bronchial problems, leprosy and infertility                          | [71]      |
| Ziziphus mucronata        | Rhamnaceae        | Bark, leaves and roots are used to treat boils, sores, glandular swellings,          | Antimycobacteria                                                                   | [72]      |
| Berchemia discolor        | Rhamnaceae        | (3 S)-discoloranone                                                                  | Infertility and Menorrhagia                                                        | Antimycobacteria                   | [66]      |
| Peltophorum africanum     | Fabaceae          | Catechin (flavonoid), bergenin, betulinic acid                                       | Used to treat tuberculosis, stomach complains and intestinal parasites             | Antimycobacteria                   | [73]      |

Rapid navigation of natural product hits through the detection, validation, isolation, and hit-to-lead and lead optimization phases [56].

Considering that none of the several screened non-microbial natural products with activity against MTB has progressed towards the clinical trial stage in anti-TB drug development, this could possibly be caused by:

i. Low yields of purified compounds;

ii. Structural complexity exhibited by natural products, such as the occurrence of multiple stereoisomers, e.g., triterpenes which contain ten or more chiral centers;

iii. Low activity exhibited by the isolated compounds with MICP 1 lg/ml;

iv. The presence of pan inhibitors (non-specific compounds or paninhibitors);

v. Difficulties in isolating novel bactericidal compounds acting on new targets that can potentially reduce the duration of therapy; and

vi. Difficulties in identification of anti-TB compounds with exceptional safety profiles without the drug-drug-interaction problem presently confronting concurrent TB and HIV therapy.

Crude natural product extracts are complex mixtures of perhaps hundreds of different compounds working together in synergy when the extract is administered as a whole. Discovery of natural product hits and their progression towards development includes extraction of the crude extract from the source, concentration, lyophilization (in cases where polar solvents have been used), fractionation and purification to yield a single bioactive compound.

Finally, it is very important to take account in that antimicrobial...
drug discovery from natural sources the endpoint criteria for activity should be below 100 μg/mL for crude extracts and 25μM or 10 μg/mL for pure compounds with the end of select new promisory antimycobacterial treatments [57,58].

Conclusion

It will be difficult to resolve the aforementioned challenges without increased funding for anti-TB drug discovery and construction of a more robust drug development pipeline through well-coordinated international efforts. Plants are sole treatment of leprosy and tuberculosis in some African countries. Though anti-mycobacterial MIC of plant materials is higher but they have resistance modifying properties. Therefore, plant derived drugs can help in fighting the drug resistance. Unfortunately, there is no plant derived molecule either in market or under trial for treatment of mycobacterial infections. Majority of studies focused on identification of crude plant extracts with anti-mycobacterial properties and has not been extended to identification of bioactive plant metabolites. Therefore, an integrated approach of identification of plants with anti-mycobacterial activity followed by identification of bioactive molecule will speed up the research and development of plant derived drug molecules for mycobacterial infections.

Acknowledgement

We acknowledge the staff and members of Fundación centro de investigación de bioprospección y biotecnología de la diversidad BIOLABB, Colombia for their kind assistance and support.

References

1. Arunkumar S, Muthuselvam M (2009) Analysis of phytochemical constituents and antimicrobial activities of Aloe vera L. against clinical pathogens. World J Agric Sci 5: 572–576. Link: https://tinyurl.com/yiq94m6j
2. Salehi B, Kumar NVA, Şener B, Sharifi-Rad M, Kilç M, et al. (2018) Medicinal Plants Used in the Treatment of Human Immunodeficiency Virus. Int J Mol Sci 19: E1459. Link: https://tinyurl.com/yd85wqnh
3. Arya V (2011) A review on anti-tubercular plants. Int J Pharm Tech Res 3: 872-880. Link: https://tinyurl.com/y69weuxo
4. Bueno J (2014) Anti-biofilm drug susceptibility testing methods: looking for new strategies against resistance mechanism. J Microbial Biochem Technol S3: 2. Link: https://tinyurl.com/yd6ic5zy
5. Sharifi-Rad J, Salehi B, Stojanović-Radić ZZ, Fokou PVT, Sharifi-Rad M, et al. (2017) Medicinal plants used in the treatment of tuberculosis - Ethnobotanical and ethnopharmacological approaches. Biotechnology Advances. Link: https://tinyurl.com/ybbb5p97
6. Bhunu B, Mautsa R, Mukanganya S (2017) Inhibition of biofilm formation in Mycobacterium smegmatis by Parinari curatellifolia leaf extracts. BMC complementary and alternative medicine 17: 285. Link: https://tinyurl.com/yj6n5jwr
7. Chah KF, Muko KN, Oboegbulem SI (2000) Antimicrobial activity of methanolic extract of Solanum torvum fruit. Fitoterapia 71: 187–189. Link: https://tinyurl.com/yb2sbq5j
8. Shariﬁ-Rad M, Varoni EM, Salehi B, Shariﬁ-Rad J, Matthews KR, et al. (2017) Plants of the Genus Zingiber as a Source of Bioactive Phytochemicals: From Tradition to Pharmacy. Molecules 22: E2145. Link: https://tinyurl.com/yxcr9f6z
9. Salehi B, Ayatollahi SA, Segura-Carretero A, Kobarfard F, Contreras MDM, et al. (2017) Bioactive chemical compounds in Eremerus persicus (Joub. & Spach) Boiss. essential oil and their health implications. Cellular and Molecular Biology 63: 1-7. Link: https://tinyurl.com/yafl6q2i
10. Shariﬁ-Rad J, Salehi B, Varoni EM, Sharopoﬁ, Yousaf Z, et al. Plants of the Melaleuca Genus as Antimicrobial Agents: From Farm to Pharmacy. Phytother Res 31: 1475-1494. Link: https://tinyurl.com/ybkmf5no
11. Chan J, Fan XD, Hunter SW, Brennan PJ, Bloom BR (1991) Lipoarabinomannan, a possible virulence factor involved in persistence of Mycobacterium tuberculosis within macrophages. Infect Immun 59: 1755–1761. Link: https://tinyurl.com/ya8c8epe
12. Balachandran C, Duraiapandiany V, Al-Dhabi NA, Balakrishna K, Kalia NP, et al. (2012) Antimycobacterial and antimycobacterial activities of methyl caffeate isolated from Solanum torvum varnum Swartz fruit. Indian J Microbiol 52: 676–681. Link: https://tinyurl.com/y9n9wxfr
13. Cos P, Vlietinck AJ, Bergehe DV, Maes L (2006) Anti-infective potential of natural products: how to develop a stronger in vitro 'proof-of-concept'. Journal of ethnopharmacology 106: 290-302. Link: https://tinyurl.com/yaoes486
14. Praveen D, Sharmishtha P (2012) Phytochemical screening and antimicrobial activity of some medicinal plants against multi-drug resistant bacteria from clinical isolates. Indian J Pharm Sci 74: 443–450. Link: https://tinyurl.com/y72pcuc9
15. Famewo EB, Clarke AM, Wild L, Ngwane A, Helden PV, et al. (2017) Anti-mycobacterial tuberculosis activity of polyherbal medicines used for the treatment of tuberculosis in Eastern Cape, South Africa. African Health Sciences 17: 780-789. Link: https://tinyurl.com/ybn3a9hp
16. Fauziyah P, Sukandar NEY, Ayuningtyas DK (2017) Combination Effect of Antituberculosis Drugs and Ethanolic Extract of Selected Medicinal Plants against Multi-Drug-Resistant Mycobacterium tuberculosis Isolates. Scientia pharmaceutica 85: 14. Link: https://tinyurl.com/y7fzgq7e
17. Fomogne-Fodjo MC, Van Vuuren S, Ndinteh DT, Krause RW, Olivier DK (2014) Antibacterial activities of plants from central Africa used traditionally by the Bakola pygmies for the treatment of respiratory and tuberculosis related symptoms. J Ethnopharmacol 155: 123–131. Link: https://tinyurl.com/y6z977dp
18. Fouotsa H, Mbaveng AT, Mbazoa CD, Nkengfack AE, Farzana S (2013). Antimicrobial constituents of three Cameroonian medicinal plants: Garcinia nobilis, Oricha suaveolens and Balsamocitrus cameronensis. BMC Complement Altern Med 13. Link: https://tinyurl.com/ybysb8ox
19. García A, Bocanegra-Garcia V, Palma-Nicolás JP, Rivera G (2012) Recent advances in antitubercular natural products, Eur J Med Chem 49: 1–23. Link: https://tinyurl.com/y9rilb8z
20. Gauza SY, Makanjuola ER, Jarym KH, Kushkit KR, Mafalug S (2013) Phytochemical composition of Allium cepa and Allium sativum and the effects of their aqueous extracts on lipid peroxidation and other hepatic biochemical parameters in female albino wistar rats. Asian J Exp Biol Sci 4: 406–410. Link: https://tinyurl.com/ycj4f53u
21. Gómez-CANsino R, GUZMÁN-GUTIÉRREZ SL, CAMPOS-LARA MG, ESPITIA-PINZÓN CI, Reyes-Chilpa R (2017) Natural compounds from mexican medicinal plants as potential drug leads for anti-tuberculosis drugs. Anais da Academia Brasileira de Ciências, (AHEAD) 89. Link: https://tinyurl.com/y7gmyz2h
22. Gupta R, Thakur B, Singh P, Singh HB, Sharma VD, et al. (2010) Anti-tuberculosis activity of selected medicinal plants against multi-drug resistant Mycobacterium tuberculosis isolates. Indian J. Med. Res. 131: 809–813. Link: https://tinyurl.com/y6v2z69h
23. Gupta VK, Kumar MM, Bisht D, Kaushik A (2017) Plants in our combating tuberculosis related symptoms. J Ethnopharmacol 155: 123–131.
strategies against Mycobacterium tuberculosis: progress made and obstacles met. Pharmaceutical Biology 55: 1536–1544. Link: https://tinyurl.com/ycw4j5vc

24. Guzman JD, Gupta A, Bucar F, Gibbons S, Bhakta S (2012) Antimycobacterials from natural sources: ancient times, antibiotic era and novel scaffolds. Front Biosci (Landmark Ed) 17: 1861–1881. Link: https://tinyurl.com/y78fj2gg

25. Hett EC, Rubin EJ (2008) Bacterial growth and cell division: a mycobacterial perspective. Microbiol Mol Biol Rev 72:126–156. Link: https://tinyurl.com/y8qk2a5c

26. Kirst HA (2013) Developing new antimicrobials through natural product research. Expert Opin Drug Discov 8: 479–493. Link: https://tinyurl.com/yof4pq73

27. Kokanova-Nedialkova Z, Nedialkov PT, Nikolov SD (2009) The genus Chenopodium: phytochemistry, ethnopharmacology and pharmacology. Pharmacoen Rev 3: 280–306. Link: https://tinyurl.com/y878l8wm

28. Luo X, Pires D, Aínsa JA, Gracia B, Duarte N, et al. (2013) Zanthoxylum capense constituents with antimycobacterial activity against Mycobacterium tuberculosis in vitro and ex vivo within human macrophages. J Ethnopharmacol 146: 417–422. Link: https://tinyurl.com/ygyqgggn

29. Mann A, Ibrahim K, Oyewale AO, Amupitan JO, Fatope MO, et al. (2011) Antimycobacterial friedelane-terpenoid from the root bark of Terminalia ivorensis. J Ethnopharmacol 133: 1021–1026. Link: https://tinyurl.com/y7gf3wrf

30. Mdluli K, Kaneko T, Upton A (2014) Tuberculosis drug discovery and emerging natural products upon drug discover. Nat Prod Rep 17: 215–234. Link: https://tinyurl.com/y9y3dt5f

31. Mehta A, Srivastva G, Kachhwaha S, Sharma M, Kothari SL (2013) Anti mycobacterial activity of Citrullus colocynthis (L.) Schrad. against drug sensitive and drug resistant Mycobacterium tuberculosis and MOTT clinical isolates. J Tuberc 59: 194–206. Link: https://tinyurl.com/ydxe3npo

32. Mitra PP (2012) Drug discovery in tuberculosis: a molecular approach. Indian J Tuberc 59: 194–206. Link: https://tinyurl.com/ydxen3po

33. Mohamad S, Zin NM, Wahab HA, Ibrahim P, Sulaiman SF, et al. (2011) Anti tuberculosis potential of some ethnobotanically selected Malaysian plants. J Ethnopharmacol 133: 1021–1026. Link: https://tinyurl.com/y7gfg2fr

34. Newman DJ, Cragg GM, Snader KM (2000) The influence of natural products upon drug discovery. Nat Prod Rep 17: 215–234. Link: https://tinyurl.com/y83dthm8

35. Sánchez JGB, Kouznetsov VV (2010) Antimycobacterial susceptibility testing methods for natural products research. Brazilian Journal of Microbiology 41: 270-277. Link: https://tinyurl.com/ybmqz2bdy

36. Sieniawska E, Swatko-Ossor M, Sawicki R, Skalicka-Woźniak K, Ginalska G (2017) Natural Terpenes Influence the Activity of Antibiotics against Isolated Mycobacterium tuberculosis. Medical Principles and Practice 26: 108-112. Link: https://tinyurl.com/ycdawkxx

37. WHO (2017) Global Tuberculosis Report 2017. WHO press: Geneva, Switzerland. Link: https://tinyurl.com/7jwscw

38. World Health Organization WHO (2017) Tuberculosis (TB) Fact sheet Reviewed March 2017. Link: https://tinyurl.com/7jwscw

39. Zofou D, Ntie-Kang F, Sippel W, Efange SM (2013) Bioactive natural products derived from the Central African flora against neglected tropical diseases and HIV. Nat Prod Rep 30: 1098-1120. Link: https://tinyurl.com/ybunxrg

40. Efange SMN (2002) Natural products: a continuing source of inspiration for drug discovery. Nat Prod Rep 17: 215–234. Link: https://tinyurl.com/y9buxzf3

41. World Health Organization (2003) Traditional medicine, Fact sheet no. 134. Geneva, WHO.

42. Harvey AL, Edrada-Ebel R, Quinn RJ (2015) The re-emergence of natural products for drug discovery in the genomics era. Nat Rev Drug Discov 14: 111–129. Link: https://tinyurl.com/y9ubnxtd

43. Lall N, Hussein AA, Meyer J (2006) Antiviral and antituberculous activity of Helichrysum melanacme constituents. Fitoterapia 77: 230–232. Link: https://tinyurl.com/yb9azxx2

44. Scotti L, Scotti MT, Mendonça FJ (2016) Editorial-Medical Chemistry applied to Natural Products in Neglected Drug Discovery. Comb Chem High Throughput Screen 19: 514-545. Link: https://tinyurl.com/y9q0b77u

45. Newman DJ, Cragg GM (2007) Natural products as sources of new drugs over the last 25 years. J Nat Prod 70: 461-477. Link: https://tinyurl.com/y9o2bd7u

46. Saleem M, Nazir M, Ali MS, Hussain H, Lee YS, et al. (2010) Antimicrobial activity of some ethnobotanically selected Malaysian plants. Anti-Infective Agents 12:178-190. Link: https://tinyurl.com/yb9y5q4t

47. Yong JN, Ntie-Kang F (2014) Potential Natural Antimycobacterial Metabolites from Some Sub-Saharan Medicinal Plants. Anti-Infective Agents 12:178-190. Link: https://tinyurl.com/y9yjy5pd

48. Yoon JH, Lim TG, Lee KM, Jeon AJ, Kim SY, et al. (2011) Tangeretin reduces ultraviolet B (UVB)-induced cyclooxygenase-2 expression in mouse epidermal cells by blocking mitogen-activated protein kinase (MAPK) activation and reactive oxygen species (ROS) generation. Agric Food Chem 59: 222-228. Link: https://tinyurl.com/y9y3q7fj

49. Babiaka S B, Ntie-Kang F, Ndingkokhok B, Lifongo L M, Mbah J A, et al (2015), RSC Adv. 5, 43242. Link: https://tinyurl.com/y97476zx

50. A. Hutchings (1996) Zulu medicinal plants, an inventory. University of Natal Press, Pietermaritzburg. Link: https://tinyurl.com/y8qka99y

51. Mujovo SF, Hussein AA, Meyer JJ, Foutie B, Muthivi T, et al. (2008) Bioactive compounds from Lippia javanica and Hoslundia opposita. Nat Prod Res 22: 1047-1054. Link: https://tinyurl.com/y9vwq0xj

52. Brendler T, van Wyk BE (2008) A historical, scientific and commercial perspective on the medicinal use of Pelargonium sidoides (Geraniaceae). J Ethnopharmacol 119: 342. Link: https://tinyurl.com/yau59k6h

53. Ngemenya MN, Mbah JA, Tane P, Titani VPK (2006) Antibacterial effects of Southern Africa. Briza Publications, Pretoria, South Africa 208.

54. Van Wyk BE, Gercke N (2000) Plants, Plants and Dental Care 2000; ch. 12, 205–2013.

55. Lawrence BM (2005) Antimicrobial/Biological Activity of Essential Oils. Allured, Illinois, Ill, USA 504. Link: https://tinyurl.com/y98rc46u

56. Kanama SK, Viljoen AM, Ketata PP, Chauwena C, Masipi M, et al. (2015) Simultaneous quantification of anthrones and chromones in Aloe ferox (“Cape aloe”) using UHPLC–MS. Phytochem Lett 13: 85-90. Link: https://tinyurl.com/yafmnb7e

57. Bapela MJ, Lall N, Isaza-Martinez JH, Regnier T, Meyer JIM, et al. (2007) Variation in the content of naphthoquinones in seeds and seedlings of Eucla natalensis. Afr J Bot 73: 606-610. Link: https://tinyurl.com/ybcs5m8r

58. van Wyk BE, Gercke N (2000) People’s Plants: A Guide to Useful Plants of Southern Africa. Briza Publications, Pretoria, South Africa 208. Link: https://tinyurl.com/ycog7zpf

59. Labuschagne E, Hussein AA, Rodrigues B, Lall N (2012) Synergistic Antimycobacterial Actions of Knowltonia vesicatoria (L.f) Sims. Evidence-Based Complementary and Alternative Medicine 2017: 843-93. Link: https://tinyurl.com/yarhw8n

60. Erasto P, Bojase-Moleta G, Majinda RRT (2004) Antimicrobial and antioxidant

Citation: Anochie PI, Ndingkokhok B, Bueno J, Anyiam FE, Ossai-Chidi LN, et al. (2018) African Medicinal Plants that Can Control or Cure Tuberculosis. Int J Pharm Sci Dev Res 4(1): 001-008. DOI: http://doi.org/10.17352/ijpsdr.000016
flavonoids from the root wood of Bolusanthus speciosus. Phytochemistry 65: 875–880. [Link: https://tinyurl.com/y9c8f2od

61. Bojase G, Wanjala CCW, Majinda RRT (2001) Two new isoflavonoids from Bolusanthus Speciosus. Bull Chem Soc Ethiop 15: 131-136. [Link: https://tinyurl.com/yadqv96k

62. Iwarsson M (1985) Leonotis. In: leistner OA (Ed.), Flora of Southern Africa 28: 31–37. [Link: https://tinyurl.com/y8zz2u7x

63. Felhaber T (1997) South African Traditional Healers’ Primary Health Care Handbook. Kagiso Publishers, Cape Town, South Africa.

64. Naidoo D, Maharaj V, Crouch NR, Ngwane A (2011) New labdane-type diterpenoids from Leonotis leonurus support circumscription of Lamiaceae s.l. Biochemical Systematics and Ecology 39: 216–219. [Link: https://tinyurl.com/yqbbcbcw

65. Green E, Samie A, Obi CL, Bessong PO, Ndip RN (2010) Inhibitory properties of selected South African medicinal plants against Mycobacterium tuberculosis. Journal of Ethnopharmacology 130: 151-157. [Link: https://tinyurl.com/y8b4br8a

66. Chin YW, Mdee LK, Mbwambo ZH, Mi Q, Chai HB, et al. (2006) Kinghorn. Prenylated flavonoids from the root bark of Berchemia discolor, a Tanzanian Medicinal Plant. Journal of Natural Products 69: 1649–1652. [Link: https://tinyurl.com/yd5v4dhw

67. Pegel KH, Rogers CB (1968) Constituents of Bridelia micrantha. Phytochemistry 7: 655–656. [Link: https://tinyurl.com/y9zov5kh

68. Okunade AL, Elvin-Lewis MPF, Lewis WH (2004) Natural antimycobacterial metabolites: current status. Phytochemistry 65: 1017–1032. [Link: https://tinyurl.com/y9vfvgf

69. More G, Lall N, Hussein A, Tshikalange TE (2012) Evidence-Based Complement. Alternative Med 252758.

70. Betti JL (2004) An ethnobotanical study of medicinal plants among the Baka pyg- mies in the Dja Biosphere reserve, Cameroon. African Study Monograms 25: 1–27. [Link: https://tinyurl.com/yc52jusj

71. Iwalewa E O, McGaw L J, Naidoo V, Eloff J N (2007) Inflammation: the foundation of diseases and disorders: A review of phytomedicines of South African origin used to treat pain and inflammatory conditions. African Journal of Biotechnology, 6, 2868–2885. [Link: https://tinyurl.com/ycytrakg

72. Arnold H, Gulumian M (1984). Pharmacopoeia of traditional medicine in Venda. Journal of Ethnopharmacology, 12,35–74. [Link: https://tinyurl.com/ydymc5pt

73. Theo A, Masebe T, Suzuki Y, Kittchi H, Wada S, et. al. (2009) Peltophorum africanum, a traditional South African medicinal plant, contains an anti-HIV constituent, betulinic acid. The Tahoku J Exp Med 217: 93-99. [Link: https://tinyurl.com/ybv2j5s

Copyright: © 2018 Anochie PI, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Citation: Anochie PI, Ndingkokhar B, Bueno J, Anyiam FE, Ossai-Chidi LN, et al. (2018) African Medicinal Plants that Can Control or Cure Tuberculosis. Int J Pharm Sci Dev Res 4(1): 001-008. DOI: http://doi.org/10.17352/ijpsdr.000016