Anti dermatophytic therapy - Prospects for the discovery of new drugs from natural products

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Abstract

Millions of people and animals suffer from superficial infections caused by a group of highly specialized filamentous fungi, the dermatophytes, which only infect keratinized structures. With the appearance of AIDS, the incidence of dermatophytosis has increased. Current drug therapy used for these infections is often toxic, long-term, and expensive and has limited effectiveness; therefore, the discovery of new anti dermatophytic compounds is a necessity. Natural products have been the most productive source for new drug development. This paper provides a brief review of the current literature regarding the presence of dermatophytes in immunocompromised patients, drug resistance to conventional treatments and new anti dermatophytic treatments.

Key words: dermatophytes, filamentous fungi, natural products, synthetic product.

Dermatophytosis

Millions of people and animals suffer from superficial infections caused by a group of highly specialized filamentous fungi, the dermatophytes, which only infect keratinized structures (Burmester et al., 2011). The American Academy of Dermatology estimates that 10-20% of the population is affected by dermatophytes (Pfaller and Sutton, 2006). Dermatophytes are a group of parasitic fungi that live at the expense of the keratin in the skin, nails and hair. These microorganisms fall into the genera Trichophyton, Microsporum and Epidermophyton, as characterized according to the formation and morphology of their conidia (Weitzman and Summerbell, 1995; White et al., 2008 Peres et al., 2010). In general, dermatophytes are confined to the stratum corneum of the epidermis and skin appendages, especially in the moist areas of the body, such as the regions between the toes, groin and below the breasts (Chuang et al., 2007). Although dermatophyte infections are restricted to areas of the epidermis, they can be invasive and cause serious widespread infections in immunocompromised patients, with the development of granulomas (Peres et al., 2010). In such cases, the disease no longer is superficial and reaches deeper layers of dermis, causing granulomatous lesions.

Dermatophytes produce proteolytic enzymes, keratinases, which are able to hydrolyze keratin, the main protein constituent of hair, nails and skin. The infection can be mild to severe, depending on the host immune response (Akcaoglar et al., 2011). The keratin, collagen and elastin constitute 25% of the mass of mammals. The enzyme required to hydrolyze these macromolecules is found in infected tissues and is therefore considered essential to the virulence of dermatophytes (Simpanya, 2000). Colonization by a dermatophyte, and its ability to cause an infection in the host, depends on several factors, among which are the “escape” mechanisms of the host resistance, including dry skin, a slightly acidic pH, the continuous regeneration skin, the fungicidal effect of fatty acids, the state of the keratinized layer and other factors, such as competition with the normal skin microbiota (Erbagci et al., 2004). The establishment of the infection is initiated by the inoculation of arthrospores deposited on the skin, favored by a pre - exist-
ing skin lesion or abrasion (Sidrim and Rocha, 2004) and the microorganism’s remarkable enzymatic ability to degrade keratin (Simpanya, 2000; Abdel-Rahman, 2001; Macêdo et al., 2005). It also can infect several animal species, creating generally dry, rounded and usually non-pruritic lesions, distributed focally on the skin without causing a general inconvenience to the affected animals (Peres et al., 2010). For treating the fungal infections of skin, topical medications are appropriate only for early or mild infections, especially those caused by T. rubrum, the main cause of Tinea pedis. In nail infections (onychomycosis) and infections caused by zoophilic dermatophytes, mainly leading to the development of Tinea capitis and corporis, the usual therapy is systemic (Tani et al., 2001; White et al., 2008). Terbinafine inhibits the growth of dermatophytes of all genera and is the main drug of choice for the treatment of dermatophytoses, especially with chronic conditions. The naftifin and terbinafine represent the group of drugs synthetic, the allylamine, which were described as drugs in clinical treatment of superficial mycoses (Balfour and Faulds, 1992). It has shown fungicidal activity against a wide range of dermatophytes, molds and certain fungi dimorphic, and fungistatic activity against Candida albicans being that terbinafine has been the drug of first choice for dermatophytes (Abdel-Rahman and Nahata, 1997; McClellan et al., 1999). Its mechanism of action relies on blocking the biosynthesis of ergosterol, an essential component of fungal cell membranes, through inhibition of fungal squalene epoxidase (Abdel-Rahman and Nahata, 1997). The tolerability of these drugs is generally high after topical administration or oral. In comparative studies, the incidence of adverse effects associated with use of terbinafine orally, was lower than that observed with griseofulvin and similar to itraconazole (Abdel-Rahman and Nahata, 1997). Terbinafine has emerged as a new therapeutic option for dermatophytoses in both humans and animals (Mancianti et al., 1999). Griseofulvin is used exclusively to control the development of keratinized tissue infection by presenting only fungistatic and not fungicidal action. This drug is orally administered and treatment varies according to the clinical form of mycosis (Gupta et al., 2001). In severe infections, the treatment must be prolonged (Deacon, 1998). The mechanism of action of this drug is associated with interfering with the polymerization of microtubules causing abnormalities in cell division due to achronic spindle formation and abnormal growth, probably due to disruption of intracellular transport associated with microtubules (Odds, 2003). Currently, imidazole derivatives represent a major advance in oral and topical treatment of superficial mycoses, with dermatophytosis specifically, clotrimazole (topical), ketoconazole, itraconazole and fluconazole are commonly used because they are absorbed through the gastrointestinal tract and maintain an effective activity (Katzung et al., 1998), with fluconazole being effective against other types of fungal infections (Follador et al., 2001; Oliveira et al., 2002). In therapy, there are two groups of antifungal azoles are used in the clinic: the imidazoles (ketoconazole, miconazole, clotrimazole and econazole) and triazoles (fluconazole, itraconazole, voriconazole and posaconazole). The use of imidazoles is limited to the treatment of superficial mycoses. Triazoles have a larger application in these therapies. In dermatology, chronic infection is treated with severe drugs such as terbinafine, itraconazole and fluconazole, which are the most used (Abdel-Rahman et al., 1998; Fernández-Torres et al., 2001; Fernández-Torres et al., 2003). In an attempt to increase the cure rate of drug treatments, combined topical and oral anti-inflammatory drugs have been used. There have recently been cases of treating onychomycosis using topical amorolfine and ciclopirox (Gupta et al., 2001).

**Resistance to Drugs**

There is a large arsenal of antifungal drugs, however, their cellular targets are limited because of the similarity that exists between fungi and host cells. Drugs that are commonly used are directed against the biosynthetic pathway (Martínez-Rossi et al., 2008). The reports of recurrences are usually associated with the discontinuation of therapy, although clinical resistance to the antifungal drug terbinafine has been described in the literature (Mukherjee et al., 2003) described a case of clinical resistance to this drug. The strain studied was taken from a patient with onychomycosis was that treated with oral terbinafine, which was not effective with the microorganism presenting cross-resistance to several other drugs, including naftina, butenafine, and tiofotato toliciate, suggesting a target-specific resistance mechanism. The report regarding their resistance...
to terbinafine has been discussed and refers to the squalene epoxidase gene mutation leading to the substitution of amino acid L393F (Osborne et al., 2006). Terbinafine resistance in mutants of the Aspergillus species was also mentioned, and this indicated that there was a mutation in the gene encoding squalene epoxidase enzyme (ErgA), resulting in high resistance to this antifungal (Rocha et al., 2006; Espinel-Ingroff, 2008). In studies on the mechanisms of resistance to the fungus *T. rubrum*, two ABC-type transporters, TruMDR1 and TruMDR2, were important in the process of resistance (Fachin et al., 2006; Maranhão et al., 2009). The clinical resistance to griseofulvin, or relapses after treatment, is common in dermatophytosis. In a study conducted by Zomorodian, et al. (2007), a decreased expression of the gene encoding beta-tubulin was observed for the fungus *T. rubrum* during drug administration, with the decrease being concentration dependent. This information contributed to a better understanding of the mechanism of action and therefore can assist in more rational use of pharmacological therapy. The in vitro resistance of an isolate can be classified as either intrinsic or acquired. Intrinsic resistance allows all normal members of a species to tolerate a particular drug. Acquired resistance is a term used when a resistant strain emerges from a population that was previously drug-sensitive (Kamai et al., 2004). The biochemical mechanisms may contribute to the phenotype of drug resistance in fungus involve a decrease in drug uptake, structural alterations in the target site and an increase in drug efflux or in intracellular target levels, gene amplification, gene transfer, gene deletion, point mutations, loss of cis- and trans-acting regulatory elements and transcriptional activation (Kamai et al., 2004). Few studies have reported mechanisms of drug resistance in dermatophytes, although more studies are required to determine the mechanisms by which resistance occurs for these pathogens.

Natural and Synthetic Products

The search for plants with healing powers for various diseases dates back many years. From prehistory to the present day, thousands of plants have been used by people of all continents, either in the form of poultices, infusions, decoctions, and others. In the 90’s, approximately of the American population had already made use of at least one type of unconventional therapy (Eisenberg et al., 1993). In this context, interest in plants with therapeutic properties including those with antimicrobial activity has grown, not just form themselves into an alternative therapeutic approach, but also because the prospect of isolating substances with significant efficacy and a lower index of disadvantage (Queiroz et al., 2009). Plants have been used in medicine for a long time, having been extensively used in folk medicine because they represent an economical alternative, are easy to obtain and are applicable to various patologies (Rojas et al., 2006). Plants are an important source of biologically active compounds, many of which are models for the synthesis of a large number of drugs (Yunes and Calixto, 2001; Simões et al., 2003). Special attention has been directed to natural derivatives, based on the knowledge of antifungal compound production in nature (Wojtaszek, 1997; Gurgel et al., 2005).

Natural products have served as a research resource for most drugs, providing a basis for chemical research and discovery of new drugs (Chin et al., 2006). Several reasons have been offered to explain the success of natural products, among them is their great chemical diversity, the effects of evolutionary pressure in creating biologically active molecules, the structural similarity of protein targets in different species, among others (Harvey, 2007). Natural products are a source of numerous agents of therapeutic value. They also inspired, at various levels, the development and manufacture of synthetic agents of therapeutic importance. These agents are synthesized by manipulating the natural product, demonstrating that the synthesis of molecules can be used to discover and develop novel therapeutic agents (Wilson and Danishefsky, 2006). An ideal antifungal drug should have a broad spectrum of fungicidal activity and not cause toxicity to the host (Carrillo-Muñoz et al., 2006). A large number of antifungal drugs have some connection with natural products. The class of polyenes and griseofulvin are natural products, whereas echinocandins are semisynthetic derivatives of natural products (Butler, 2005). Currently, antibiotics and antifungals represent a small group of drugs which plays an important role in fungal disease control, however, some of these antifungals have serious drawbacks such as toxicity, fungistatic activity, limited spectrum of action or resistance (García-Sosa et al., 2011). The great importance of natural products in developing new therapeutic tools is evident. In this aspect, medicinal plants and their derivatives are important for pharmacological research and drug development. These natural products can be used directly as therapeutic agents, as well as a source of raw materials for synthesis, or can serve as prototypes for new pharmacologically active models (Brazil, 2006).

Fructus Psoraleae and Folium Eucalypti Globuli have long been used as Chinese medicines to treat dermatomycosis. Both pure compounds effectively inhibit the in vitro growth of *T. mentagrophytes* and *T. rubrum* (Lau et al., 2010). In the study of Eisenberg et al. (1993) a volatile extract of *Eryngium duriaeui subsp. juresianum* presents an antifungal activity (Minimal inhibitory concentration (MIC) values = 0.16-0.32 μg/mL (-1)) against several dermatophyte species (*T. mentagrophytes, T. rubrum, E. floccosum; T. verrucosum, T. mentagrophytes var. interdigitale, M. canis and M. gypseum*) (Eisenberg et al., 2010). Machado et al. (2009) evaluated the antifungal activity of *Eugenia unibaliliflora Berg.* against some dermatophytes (*E. floccosum, M. canis, M. gypseum, T. rubrum, T. mentagrophytes*) and obtained good results, with MIC values between 200 and 1000 microg/mL, and in-
terestingly, inhibited 4/5 species with MIC values of < or = 500 microg/mL. Koroishi et al. (2008) studied the Piper regnellii extract, with the results indicating that this plant had strong activity against T. mentagrophytes, T. rubrum, M. canis and M. gypseum. Park et al. (2011) found good results against various pathogenic fungi (species dermatophytes) with the polyphenol Epigallocatechin 3-O-Gallate (Table 1). The antifungal activities of the essential oils (EOs) of Acantholippia serpioides, Artemisia mendozana, Gymnophyton polypephalum, Satureja parvifolia, Tagetes mendocina, and Lippia integrifolia, collected in the Central Andes area, province of San Juan, Argentina, were investigated against M. gypseum. The major compound, identified as indirubin, exhibited activity against dermatophytes such as T. rubrum, E. floccosum, Aspergillus niger and Scopulariopsis brevicaulis. The major compound, identified as indirubin, exhibited activity against dermatophytes such as E. floccosum (MIC = 6.25 μg/mL); T. rubrum and T. tonsurans (MIC = 25 μg/mL); T. mentagrophytes and T. simii (MIC = 50 μg/mL). It was also active against non-dermatophytes (Aspergillus niger, Candida albicans and Cryptococcus sp.) within a MIC range of 0.75-25 μg/mL. All of the new chemical entities approved as drugs between 1981-2006 total almost 1,184 products, with 5% as natural products, 47% as semi-synthetic derivatives of natural products, mimicking natural products and products synthesized with pharmacological groups based on natural products, 18% as by-products and vaccines and 30% as fully synthetic products (Newman and Cragg, 2007). The originality of many structures of natural products attracts attention to their use as a starting point for semi-synthesis and total synthesis (Butler, 2005). Soares et al. (2010) used semi-synthetic esters of protocatechuic acid isolated from Cupania oblongifolia against T. rubrum and T. mentagrophytes, demonstrating an antifungal activity with MIC values lower than 31.25 μg/mL. The modification of natural products by semi-synthesis has led to different types of drug combinations. The development of chemotherapeutic agents of synthetic origin and the discovery of powerful new antimicrobians isolated from natural sources account for invaluable contributions in the fight against bacterial and fungal resistance (Silveira et al., 2006). Pisseri et al. (2009) conducted a randomized open clinical trial on 60 thorough breeding horses affected by equine ringworm using Tea Tree Oil (TTO). The animals were randomly divided into 2 groups of 30 subjects. Diagnostic criteria were the presence of clinical signs and positive Trichophyton equinum culture. Specificity control using TTO mixture in 5 not dermatophyte affected animals was achieved also. The antymycotic activity against T. equinum of a mixture containing 25% TTO in sweet almond oil, was evaluated in vivo treating 30 subjects, the others were administered enilconazole 2% solution. The animals of both groups were topically treated twice a day for 15 days with a 25% mixture of TTO diluted in sweet almond oil and every 3 days, four times with enilconazole rinses, respectively. All the treated animals showed complete clinical and etiological healing. Part of control subjects also, showed an improvement and none of them exacerbate the lesions. The authors believe this TTO an alternative for practitioners interested in herbal medicines, contributing to fulfill the gap existing between

Table 1 - Antifungal activity of natural products against a variety dermatophytes.

| Natural Products                          | Microorganisms                                      | Reference            |
|------------------------------------------|-----------------------------------------------------|----------------------|
| Citrus bergamia (Rutaceae)               | T. rubrum, T. mentagrophytes T. tonsurans, M. canis, M. gypseum E. floccosum | Sanguinetti et al., 2007 |
| Brazilian Copaiba Oil (Fabaceae)         | T. rubrum, M. Canis                                  | Santos et al., 2008  |
| Piper regnellii (Piperaceae)              | M. canis, M. gypseum, T. rubrum, T. mentagrophytes  | Koroishi et al., 2008|
| Syzygium aromaticum (Myrtaceae)          | M. canis, M. gypseum, T. rubrum, T. mentagrophytes, E. floccosum | Pinto et al., 2009   |
| Eugenia umbelliflora Berg. (Myrtaceae)   | M. canis, M. gypseum, T. rubrum, T. mentagrophytes, E. floccosum | Machado et al., 2009 |
| Fructus Psoraleae (Leguminosae)          | T. rubrum, T. mentagrophytes                         | Lau et al., 2010     |
| Protocatechuic acid (Cupania oblongifolia) (Sapindaceae) | T. rubrum, T. mentagrophytes                         | Soares et al., 2010  |
| Folium Eucalypti Globuli (Leptospermaraceae) | T. rubrum, T. mentagrophytes                         | Lau et al., 2010     |
| Eryngium duriae subsp. Juresianum (Umbelliferae) | T. mentagrophytes, T. rubrum, E. floccosum, T. verrucosum, T. mentagrophytes var interdigitate, M. canis and M. Gypseum | Cavaleiro et al., 2011|
| Xanthones (Clusiaceae)                   | M. canis, M. gypseum, T. rubrum, T. mentagrophytes, E. floccosum | Pinto et al., 2011   |
| Epigallocatechin 3–O- Gallate (green tea) (Theaceae) | M. canis, T. rubrum, T. mentagrophytes               | Park et al., 2011    |
in vitro and clinical studies. The extracts obtained from plants, such as *Euphorbia prostrata*, *Salvia Texana*, *Colubrina greggii*, *Clematis drummondii*, among others, have shown promising results for stimulating the search for new potential antifungal plant sources (Alanis-Garza et al., 2007). Most antifungal drugs have a connection to natural products, it can be seen the potential antimicrobial plant products, and consequently, the real possibility of application of these products in the prevention and treatment of infectious diseases of fungal origin. However, it is necessary to mention the need for toxicological studies and clinical and security support for the use of these products as drugs.

**Conclusion**

Millions of people and animals suffer from superficial infections caused by a group of highly specialized filamentous fungi, the dermatophytes. Interest in medicinal plants has increased, especially in Brazil, due to the fact of the vast diversity of plants with therapeutic potential. It is necessary to search for new drugs because of the increase of resistant isolates. More studies are needed to develop drugs for dermatophytosis, since the conventional drugs used for this pathology, while being cytotoxic, often lead to clinical resistance.

**References**

Abdel-Rahman SM (2001) Polymorphic exocellular protease expression in clinical isolates of *Trichophyton tonsurans*. Mycopathologia. 150:117-120.

Abdel-Rahman SM, Nahata MC (1997) Oral terbinafine: a new antifungal agent. Ann Pharmacother 31:445-456.

Abdel-Rahman SM, Powell DA, Nahata MC (1997) Efficacy of itraconazole in children with *Trichophyton tonsurans* tinea capitis. J Am Acad Dermatol 38:443-446.

Akcaglar S, Ener B, Toker SC, Ediz B, Tunali S, Tore O (2011) A comparative study of dermatophyte infections in Bursa, Turkey. Med Mycol 49:602-607.

Alanis-Garza BA, González-González GM, Salazar-Aranda R, Waksman de Torres N, Rivas-Galindo VM (2007) Screening of antifungal activity of plants from the northeast of Mexico. J Ethnopharmacol 114:468-471.

Baaza LC, Bailão AM, Borges CL, Pereira M, Soares CM, Mendes-Giannini MJ (2007) cDNA representational difference analysis used in the identification of genes expressed by *Trichophyton rubrum* during contact with keratin. Microbes Infect 9:1415-1421.

Balfour JA, Faulds D (1992) Terbinafine A review of its pharmacodynamic and pharmacokinetic properties, and therapeutic potential in superficial mycoses. Drugs 43:259-284.

Baranova Z, Kozak M, Bilek J (2003) Zoophilic dermatomycosis in a family caused by *Trichophyton mentagrophytes* var. *quinceanum* - A case report. Acta Vet Brno 72:311-314.

Brazil (2006) Ministry of Health SdC, Tecnology and Estrategic Inputs. National policy of medicinal plants and herbal medicine. In: Pharmaceuticals DDA editor. Brasilia.

Burmester A, Shelest E, Glöckner G, Heddergott C, Schindler S, Staib P, Heidel A, Felder M, Petzold A, Szafranski K, Feuermann M, Peduzzi I, Priebe S, Groth M, Winkler R, Li W, Kniemeyer O, Schroechv K, Hertweck C, Hube B, White TC, Platzer M, Guthke R, Heitman J, Wöstemeyer J, Zipfel PF, Monod M, Brakhage AA (2011) Comparative and functional genomics provide insights into the pathogenicity of dermatophytic fungi. Genome Biol 12:R7.

Butler MS (2005) Natural products to drugs: natural product derived compounds in clinical trials. Nat Prod Rep 22:162-195.

Butler MS (2005) Natural products to drugs: natural product derived compounds in clinical trials. Nat Prod Rep 22:162-195.

Cabañes FJ (2000) Emerging mycotoxins: introduction. Rev. Iberoam Micol 17:S61-S62.

Carrillo-Muñoz AJ, Giusiano G, Ezkurra PA, Quindós G (2006) Antifungal agents: mode of action in yeast cells. Rev Esp Quimioter 19:130-139.

Cavaleiro C, Gonçalves MJ, Serra D, Santoro G, Tomi F, Bighelli A, Salgueiro L, Casanova J (2011) Composition of a volatile extract of *Eryngium duriae* subsp. *juresianum* (M. Laínz) M. Laínz, signalised by the antifungal activity. J Pharm Biomed Anal 54:619-622.

Chin YW, Balunas MJ, Chai HB, Kinghorn AD (2006) Drug discovery from natural sources. AAPS Journal 8:E239-253.

Chuang PH, Lee CW, Chou JY, Murugan M, Shieh BJ, Chen HM (2007) Anti-fungal activity of crude extracts and essential oil of *Moringa oleifera* Lam. Bioresour Technol 98:232-236.

Deacon JW (1998) Introduction to modern mycology. 3rd ed. Blackwell, Oxford.

Eisenberg DM, Kessier RC, Foster C, Norlock FE, Calkins DR, Delbanco TL (1993) Unconventional Medicine in the United States - Prevalence, Costs, and Patterns of Use. N Engl J Med 328:246-252.

Eisenberg DM, Kessier RC, Foster C, Norlock FE, Calkins DR, Delbanco TL (1993) Unconventional Medicine in the United States - Prevalence, Costs, and Patterns of Use. N Engl J Med 328:246-252.

Erbagci Z (2004) Topical therapy for dermatophytoses: should corticosteroids be included? Am J Clin Dermatol 5:375-384.

Espinel-Ingroff A (2008) Mechanisms of resistance to antifungal agents: yeasts and filamentous fungi. Rev Iberoam Micol 25:101-106.

Fachin AL, Ferreira-Nozawa MS, Maccheroni W, Martinez-Rossi NM (2006) Role of the ABC transporter TruMDR2 in terbinafine, 4-nitroquinoline N-oxide and ethidium bromide susceptibility in *Trichophyton rubrum*. J Med Microbiol 55:1093-1099.

Fernández-Torres B, Carrillo AJ, Martín E, Del Palacio A, Moore MK, Valverde A, Serrano M, Guarro J (2001) In vitro activities of 10 antifungal drugs against 508 dermatophyte strains. Antimicrob Agents Chemother 45:2524-2528.

Fernández-Torres B, Inza I, Guarro J (2003) In vitro activities of the new antifungal drug eberconazole and three other topical agents against 200 strains of dermatophytes. J Clin Microbiol 41:5209-5211.

Follador I, Bittencourt A, Duran F, das Graças Araújo MG (2001) Cutaneous protothecosis: report of the second Brazilian case. Rev Inst Med Trop São Paulo 43:287-290.

García-Sosa K, Sánchez-Medina A, Álvarez SL, Zacchino S, Veitch NC, Simá-Polanco P, Peña-Rodriguez LM (2011)
Antifungal activity of sakuraskosaponin from the root extract of *Jacquinia flammea*. Nat Prod Res 25:1185-1189.

Gupta AK, Adam P, Dloue N, Lynde CW, Hofstader S, Morar N, Abobaker J, Summerbell RC (2001) Therapeutic options for the treatment of tinea capitis caused by *Trichophyton* species: griseofulvin vs. the new oral antifungal agents, terbinafine, itraconazole, and fluconazole. Pediatr Dermatol 18:433-438.

Gupta AK, Adam P, Dloue N, Lynde CW, Hofstader S, Morar N, Abobaker J, Summerbell RC (2001) Therapeutic options for the treatment of tinea capitis caused by *Trichophyton* species: griseofulvin vs. the new oral antifungal agents, terbinafine, itraconazole, and fluconazole. Pediatr Dermatol 18:433-438.

Gurgel LA, Sidirim JJ, Martins DT, Cechinel Filho V, Rao VS, Lima B, López S, Luna L, Aragón L, Tapia A, Vooeux PJ (1998) Diseases caused by fungi and insect-repellent activities. Chem Biodivers 5:36-37.

Harvey AL (2007) Natural products as a screening resource. Curr Opin Chem Biol 11:480-484.

Kamai Y, Maebashi K, Kudoh M, Makimura K, Naka W, Uchida K, Yamaguchi H (2004) Characterization of mechanisms of fluconazole Characterization of mechanisms of fluconazole resistance in a *Candida albicans* isolate from a Japanese patient with chronic mucocutaneous candidiasis. Microbiol Immunol 48:937-943.

Katzung GB, Silva P, Mundim FD, Vooeux PJ (1998) Basic and clinical pharmacology. Editora Guanabara Koogan, Rio de Janeiro, Brazil.

Koroishi AM, Foss SR, Cortez DA, Ueda-Nakamura T, Nakamura CV, Dias Filho VB (2008) In vitro antifungal activity of extracts and neolignans from *Piper regnellii* against dermatophytes. J Ethnopharmacol 117:270-277.

Lau KM, Fu LH, Cheng L, Wong CW, Wong YL, Lau CP, Hau SQ, Chan PK, Fung KP, Lau CB, Hui M, Leung PC (2010) Two antifungal components isolated from *Fructus Psoraleae* and *Foliolum Eucalypti Globuli* by bioassay-guided purification. Am J Chin Med 38:1005-1014.

Lima B, López S, Luna L, Águero MB, Aragón L, Tapia A, Zacchino S, López ML, Zygadlo J, Feresin GE (2011) Antifungal activity of the clove essential oil from *Syzygium aromaticum* on *Candida, Aspergillus* and dermatophyte species. J Med Microbiol 58:1454-1462.

Macêdo DP, Neves RP, Neves RP, Magalhães MC, Souza-Motta CM., Queiroz LA (2005) Pathogenic aspects of *Epidermophyton floccosum* Langeron et Micochevich as a possible ethiologial agent of *Tinea capitis*. Braz J Microbiol 36:36-37.

Machado KE, Cechinel-Filho V, Cruz RC, Meyre-Silva C, Cruz AB (2009) Antifungal activity of *Eugenia umbelliflora* against dermatophytes. Nat Prod Commun 4:1181-1184.

Mancianti F, Pedonese F, Millanta F, Guarnieri L (1999) Efficacy of oral terbinafine in feline dermatophytosis due to *Microsporum canis*. J Feline Med Surg 1:37-41.

Maranhão FC, Paião FG, Fachin AL, Martinez-Rossi NM (2009) Membrane transporter proteins are involved in *Trichophyton rubrum* pathogenesis. J Med Microbiol 58:163-168.

Martinez-Rossi NM, Peres NT, Rossi A (2008) Antifungal resistance mechanisms in dermatophytes. Mycopathologia 166:369-383.

McClellan KJ, Wiseman LR, Markham A (1999) Terbinafine. An update of its use in superficial mycoses. Drugs 58:179-202.

Monod M (2008) Secreted proteases from dermatophytes. Mycopathologia 166:285-294.

Mukherjee PK, Leidich SD, Isham N, Leitner I, Ryder NS, Ghannoum MA (2003) Clinical *Trichophyton rubrum* strain exhibiting primary resistance to terbinafine. Antimicrob Agents Chemother 47:82-86.

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

Odds CF (2003) Antifungal agents: Their diversity and increasing sophistication. Mycologist 17:51-55.

Oliveira JS, Kerbauy FR, Colombo AL, Bahia DM, Pinheiro GS, Silva MR, Ribeiro MS, Raineri G, Kerbauy J (2002) Fungal infections in marrow transplant recipients under antifungal prophylaxis with fluconazole. Braz J Med Biol Res 35:789-798.

Osborne CS, Leitner I, Hofbauer B, Fielding CA, Favre B, Ryder NS (2006) Biological, biochemical, and molecular characterization of a new clinical *Trichophyton rubrum* isolate resistant to terbinafine. Antimicrob Agents Chemother 50:2234-2236.

Park BJ, Taguchi H, Kamei K, Matsuzawa T, Hyon SH, Park JC (2011) In vitro antifungal activity of epigallocatechin 3-O-gallate against clinical isolates of dermatophytes. Yonsei Med J 52:535-538.

Pereira DB, Meireles MCA (2001) Diseases caused by fungi and Oomycetes. Diseases of ruminants and horses 4:367-383.

Peres NT, Maranhão FC, Rossi A, Martinez-Rossi NM (2010) Dermatophytes: host-pathogen interaction and antifungal resistance. An Bras Dermatol 85:657-667.

Pfäller MA, Sutton DA (2006) Review of in vitro activity of sertaconazole nitrate in the treatment of superficial fungal infections. Diagn Microbiol Infect Dis 56:147-152.

Pinto E, Afonso C, Duarte S, Vale-Silva L, Costa E, Sousa E, Pinto M (2011) Antifungal activity of xanthones: evaluation of their effect on ergosterol biosynthesis by high-performance liquid chromatography. Chem Biol Drug Des 77:212-222.

Pinto E, Vale-Silva L, Cavaleiro C, Salgueiro L (2009) Antifungal activity of the clove essential oil from *Syzygium aromaticum* on *Candida, Aspergillus* and dermatophyte species. J Med Microbiol 58:1454-1462.

Pissiery F, Bertoli A, Nardoni S, Pinto L, Pistelli L, Guidi G, Mancianti F (2009) Antifungal activity of tea tree oil from *Melaleuca alternifolia* against *Trichophyton equinum*; an in vivo assay. Phytotherapy 16:1056-1058.

Ponnusamy K, Petchiammal C, Mohankumar R, Hopper W (2010) In vitro antifungal activity of indirubin isolated from a South Indian ethnomedicinal plant *Wrightia tinctoria*. Br J Ethnopharmacol 132:349-354.

Queiroz EF, Wolfender JL, Hostettmann K (2009) Modern approaches in the search for new lead antiparasitic compounds from higher plants. Current Drugs 10:202-211.

Rocha EM, Gardiner RE, Park S, Martinez-Rossi NM, Perlin DS (2006) A Phe389Leu substitution in ergA confers terbinafine resistance in a clinical isolate of *Aspergillus fumigatus*. Antimicrob Agents Chemother 50:2234-2236.

Rojas JJ, Ochoa VJ, Ocampo AS, Muñoz JF (2006) Screening for antimicrobial activity of ten medicinal plants used in Colombian folkloric medicine: a possible alternative in the search for new lead antiparasitic compounds from higher plants. Current Drugs 10:202-211.
treatment of non-nosocomial infections. BMC Complement Altern Med 17:2.

Sanguinetti M, Posteraro B, Romano L, Battaglia F, Lopizzo T, De Carolis E, Fadda G (2007) In vitro activity of *Citrus bergamia* (bergamot) oil against clinical isolates of dermatophytes. J Antimicrob Chemother 59:305-308.

Santos AO, Ueda-Nakamura T, Dias Filho BP, Veiga Junior VF. Pinto AC, Nakamura CV (2008) Antimicrobial activity of Brazilian copaiba oils obtained from different species of the *Copaifera* genus. Mem Inst Oswaldo Cruz 103:277-281.

Sidrim JJC, Rocha MFG (2004) Medical Mycology light of authors contemporâneos. Guanabara Koogan. Rio de Janeiro, Brasil.

Silveira GP, Nome F, Gesser JC, Sá MM, Terenzi T (2006) The strategies used to combat bacterial resistance. Química Nova 29:844-855.

Simões CMO, Schenkel EP, Gosmann MG, Mello JCP, Ments LA, Petrovick PR (2003) *Pharmacognosy: The medicinal plant - products of plant origin and development of drugs*. 5th ed. p. 291-320.

Simpanya MF (2000) *Dermatophytes: Their taxonomy, ecology and pathogenicity*. Rev Iberoam Micol 17:1-12.

Soares LA(2011) *Estudy of the activity antidermatophytic of protocatechuate against T. rubrum and T. interdigitale*. Araraquara, São Paulo, Brazil, 85 p. (M.Sc. Dissertation Faculty of Pharmaceutical Sciences: University Estadual Paulista Júlio Júlio Mesquita Filho – UNESP).

Sobestiansky J (2001) Clinical and Swine Pathology e Patologia Suina. Goiânia: Gráfica Art3. 2ed. p. 463.

Tani K, Adachi M, Nakamura Y, Kano R, Makimura K, Hasegawa A, Kanda N, Watanabe S (2007) The effect of dermatophytes on cytokine production by human keratinocytes. Arch Dermatol Res 299:381-387.

Weitzman I, Summerbell RC (1995) The dermatophytes. Clin Microbiol Rev 8:240-259.

White TC, Oliver BG, Gräser Y, Henn MR (2008) Generating and testing molecular hypothesises in the dermatophytes. *Eukaryot Cell* 7:1238-1245.

Wilson RM, Danishefsky SJ (2006) Small molecule natural products in the discovery of therapeutic agents: the synthesis connection. *J Org Chem* 71:8329-8351.

Wojtaszek P (1997) Oxidative burst: an early plant response to pathogen infection. *Biochem J* 322:681-692.

Yunes RA, Calixto JB (2001) *Plantas medicinais sob óptica da química medicinal moderna*. 2001. Moderna – Chapecó: Argos.

Zomoreodian K, Uthman U, Tarazoioe B, Rezaie S (2007) The effect of griseofulvin on the gene regulation of beta-tubulin in the dermatophyte pathogen *Trichophyton rubrum*. *J Infect Chemother* 13:373-379.

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