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# Keratinophilic Fungi Distribution, Pathogenicity and Biotechnological Potentials

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## Abstract

This chapter discusses the occurrence of keratinophilic fungi in different habitats wherein the population of these fungi is expected to occur: air, soil from various environments like gardens, caves, cold and saline habitat. The ability to degrade the keratinic material and mechanism of action is discussed. Importance of these fungi in petroleum hydrocarbon degradation is discussed. Various metabolites with antibacterial, antifungal, antitumor and related compounds produced by this group of fungi are documented. Examples of synthesis of silver nanoparticles are also included. The need for an extensive survey of keratinophilic fungi from unexplored substrates and habitats and biochemical potentialities is highlighted. It is concluded that fungi other than dermatophytes can be opportunistic pathogens. The need for a culture collection of this group of fungi is also highlighted.

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## Keywords

Keratinophilic fungi • Extreme climate • Secondary metabolites  
Culture collection • Keratin degradation • Silver nanoparticles • Database

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## Introduction

Keratin is a natural fibrous protein which forms the outermost keratinized layer of the skin and its appendages in man and animals. Keratin contains high sulphur-containing aminoacid, e.g., cysteine and methionine which makes it resistant to microbial degradation. Keratin is colonized and degraded by soil microorganisms, principally keratinophilic fungi. The presence of disulphide bridges makes keratin poorly biodegradable (Gopinath et al. 2015). These fungi have a number of common morphological and physiological characters and are members of the primitive Ascomycetes family, Gymnoascaceae. Within this family, there are number of species which are able to decompose keratin while they are still a part of man and animals. This article covers the different habitats from where these fungi are frequently recorded followed by the pathogenicity of these fungi, their ability to degrade keratin, petroleum products and to produce bioactive metabolites and synthesis of nanoparticles.

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## Distribution of Keratinophilic Fungi

### Soil in General

The distribution of dermatophytes in soil was reported by Vanbreuseghem (1952). Later on, various researchers isolated these fungi from soils of different countries, i.e. Australia (McAleer 1980), Egypt (Abdel-Hafez and El-Sharouny 1987; Zaki et al. 2005), Nigeria (Ogbonna and Pugh 1987), West Bank of Jordan (Ali-Shtayeh 1989), Kuwait (Al-Musallam 1989), Spain (Calvo et al. 1984; Ulfig et al. 1997), New Guinea (Filipello Marchisio et al. 1991), Malaysia (Soon 1991), Antarctica (Mercantini et al. 1993), France (Agut et al. 1995), Italy (Caretta et al. 1990; Papini et al. 1998), Palestine (Ali-Shtayeh et al. 2002), Bahrain (Deshmukh et al. 2008), Iran (Kachuei et al. 2012), West Indies (Gugnani et al. 2012), Jamaica (Gugnani et al. 2014), Argentina (Sarmiento et al. 2015) and Tunisia (Anane 2012; Anane et al. 2015).

Dey and Kakoti (1955) reported *Microsporium gypseum* for the first time from the soils of Dibrugarh district of Assam, India. Later on these fungi were isolated from various Indian states which included Delhi (Randhawa and Sandhu 1965), Madhya Pradesh (Kushwaha and Agrawal 1976; Deshmukh and Agrawal 1983a), Bihar (Verma et al. 1982), Jharkhand (Kumar et al. 2012), Uttar Pradesh (Nigam 1987; Deshmukh and Verekar 2011a), Jammu and Kashmir (Kaul and Sumbali 2000a; Deshmukh 2002a), Rajasthan (Jain and Sharma 2011), Karnataka (Deshmukh et al. 2000; Vidyasagar et al. 2005), Orissa (Roy et al. 1972; Ghosh and Bhatt 2000), Goa (Deshmukh and Agrawal 1983b), Maharashtra (Padhye et al. 1966, 1967; Deshmukh 1999; Deshmukh and Verekar 2014a), Madras (Ramesh and Hilda 1998–99; Deshmukh and Verekar 2011b), Kerala (Deshmukh 2002b), the Andamans (Dixit and Kushwaha 1990), Himachal Pradesh (Deshmukh and Verekar 2006a),

Ladakh (Deshmukh et al. 2010; Kotwal and Sumbali 2014), Gujarat (Deshmukh and Verekar 2014b), Assam (Deshmukh et al. 2017) and Chhattisgarh (Deshmukh and Shukala 2000). Some of the dermatophytes and other keratinophilic fungi are responsible for superficial infections in human and animals and are therefore of possible significance in human welfare (Emmons et al. 1977; Monga and Mohapatra 1980; De Hoog and Guarro 1995).

Various distribution patterns of occurrence of these fungi are reported. These fungi are mainly reported from the locality frequented by man and animals. In most of these studies of keratinophiles, soil samples were taken randomly from the surface and at a depth not exceeding 3–10 cm from cattle farms, gardens, roadsides, forests, watercourse banks, grasslands, animal house floors and poultry farms. These studies established universal distribution pattern of keratinophilic fungi in soils with high frequency in the habitats frequently inhabited by humans and animals. As keratinophilic fungi have been reported from soils of various habitats of different geographical areas of the world, hence of epidemiological significance. Some of the habitats from where these fungi are prevalent, are described below.

### Alkaline Soil

*Usar* soil is an alkaline soil and cover barren lands in India. Usar soil is commonly found in the area with poor/no drainage and less percolation. The soil is white alkaline type with pH of 7.5–11.0. Areas with alkaline soils show prominent whitish salt excess, with low moisture content, high temperature, drought and intense solar radiations for the most of the months of the year. These soils have scanty vegetation in the form of patches of poor grass growth. Deshmukh and Verekar (2011a) reported *Chrysosporium indicum*, *C. lucknowense*, *C. pannicola*, *C. tropicum*, *Chr. state of Ctenomyces serratus*, *Gymnascella dankailensis*, *Gymnoascus reessii*, *Microsporium gypseum*, *Trichophyton mentagrophytes* and *T. terrestre* from *Usar* soils of Lucknow, Bareilly, Azamgarh, Balia and Pratapgarh districts of Uttar Pradesh. Similarly, *Trichophyton verrucosum*, *T. mentagrophytes*, *Microsporium audouinii*, *M. canis* and *Chrysosporium tropicum* were isolated from the soils collected from the vicinity of Jaipur where pH ranges from 6.5 to 8.5 (Jain and Sharma 2011).

### Public Parks

The local residents frequently visit public parks especially for morning/evening walks. Many of them bring their pets along with them. Part of the park is completely dedicated to children having swings, slides, small playground, etc. Due to lack of proper fencing these parks are some time invaded by animals such as buffalo's, cows, bullocks, horses and pigs. The rat's borrows are also seen in the

parks. The common birds are also seen in this park. Due to human and animal activity, the keratinous material is added to the park soil. The organic matters like keratin, faeces of animals and other organic matters residues provide suitable environment for the growth of these fungi with resultant health risk. There are reports of these fungi from public parks of Agra, Kanpur and Lucknow, and the list includes *C. carmichaelii*, *C. georgii*, *C. indicum*, *C. keratinophilum*, *C. queenslandicum*, *C. tropicum*, *C. xerophilum*, *C. zonatum*, *Ctenomyces serratus*, *Geomyces pannorum*, *Gymnoascus hyalinospora*, *M. gypseum*, *M. fulvum*, *M. vanbreuseghmii*, *M. nanum*, *Malbranchea pulchella*, *Myceliophthora vellera*, *Nannizzia gypsea*, *T. verrucosum* and *T. mentagrophytes* (Singh and Kushwaha 2010). While surveying keratinophilic fungi from the five public parks of Mumbai 11 species of 8 genera were recorded, viz. *Arthrographis kalrae*, *Auxarthron conjugatum*, *C. indicum*, *C. queenslandicum*, *C. zonatum*, *Gymnascella dankaliensis*, *G. hyalinospora*, *M. gypseum*, *Myriodontium keratinophilum*, *Trichophyton mentagrophytes* and *Uncinocarpus reesii*. Occurrence of keratinophilic fungi in public parks of Mumbai is of public health concern (Deshmukh and Verekar 2012).

More recently Pakshir et al. (2013) isolated keratinophilic fungi from soils of number of parks in Shiraz, and the list includes *Chrysosporium* sp., *Microsporium gypseum*, *M. fulvum*, *Malbranchea* sp. *Phialophora reptans*, *Bipolaris spicifera*, *Bionectria ochroleuca*, *Ochroconis constricta*, *Scedosporium dehoogii*, *Cephalosporium curtipes*, *Nectria mauritiicola*, *Scedosporium apiospermum*, along with the species of *Fusarium*, *Acremonium*, *Penicillium*, *Chaetomium Scopulariopsis* and *Tritirachium* sp. Majority of these fungi were recovered from the soils where pH ranges from 7 to 8. These reports highlighted that the soils of public parks are heavily contaminated with dermatophytes and other keratinophilic fungi.

## Grazed Pastures

*Arthroderma multifidum*, *A. uncinatum*, *Clonostachys rosea*, *Engyodontium album*, *Chrysosporium* sp., *Chrysosporium keratinophilum*, *Malbranchea* sp., *Microsporium* sp., *M. vallerea*, *Paecilomyces carneus*, *P. lilacinus*, *Pochonia chlamydosporia*, *Trichophyton ajelloi*, *T. terrestre* and *Verticillium* sp. were recovered from the soils of long-term fold-grazed pastures in national parks of Slovakia and non-fold-grazed pasture in sierra Stolické vrchy. *Trichophyton ajelloi* and *P. lilacinus* were prevalent in all the soil samples. In the fold-grazed pasture, keratinophilic fungi were more abundant in compared to non-fold-grazed pasture. Substantially lower presence of the other keratinophilic fungi in non-fold-grazed pasture may be because of low pH of these soils (Javoreková et al. 2012).

## Potted Plants

Hedayati et al. (2004) isolated *Microsporium gypseum*, *M. cookei* and *Chrysosporium* sp. from the soils samples of potted plants from hospitals in Sari, Iran. The presence of these fungi in potted plants in hospitals could be a potential source of infection. Similarly, the soil samples of potted plants inside houses, hotels and offices from 15 localities of Kanpur, India, yielded *Acremonium* sp., *Acremonium implicatum*, *A. hennbertii*, *Aphanoascus terreus*, *A. keratinophilic*, *Arthroderma cuniculi*, *Botryotrichum piluliferum*, *Chrysosporium indicum*, *C. keratinophilum*, *C. queenslandicum*, *C. pannicola*, *C. sulfureum*, *C. merdarium*, *C. zonatum*, *C. tropicum*, *Ctenomyces serratus*, *Malbranchea pulchella*, *Microsporium gypseum*, *Trichophyton vanbreseghmii* and *Verticillium tenuipes*. Occurrence of these fungi in soils of indoor plants may be the source of dermatomycosis and other diseases in human (Singh et al. 2009a, b).

## Waterlogged Conditions

Paddy fields are in waterlogged condition during different stages of cultivation and personnel involved in planting rice sapling spend 8–10 h per day in warm and wet conditions in the field that favours growth of these fungi. Sundaram (1987) reported *Microsporium gypseum*, *M. canis*, *Trichophyton terrestre*, *Trichophyton* sp., *T. ajelloi*, *Chrysosporium keratinophilum*, *Aspergillus fumigatus*, *Penicillium* sp. and *Mycelia sterilia* from the rice field near Madras. *Chrysosporium* anamorph of *Arthroderma cuniculi*, *C.* anamorph of *Arthroderma curreyi*, *C. carmichaeli*, *C. georgii*, *C. gourii*, *C. indicum*, *C. keratinophilum*, *C. lobatum*, *C. merdarium*, *C. pannicola*, *C. queenslandicum*, *C. tropicum*, *C.* anamorph of *Pectinotricum illiase*, *C.* anamorph of *Rollandina vriesii* were isolated from paddy fields during different stages of cultivation, eg., transplanting, tillering, milking and maturation (Shrivastava et al. 2008). *Chrysosporium keratinophilum* followed by *C. tropicum* was the most dominating geophilic species. These fungi were most prevalent during the milking stage (100%), followed by the maturation stage (89.47%) of paddy cultivation.

## Sediments

Abdel-Hafez and el-Sharouny (1990) isolated *Chrysosporium* state of *Arthroderma tuberculatum*, *C. asperatum*, *C. georgii*, *C. indicum*, *C. keratinophilum*, *C. pseudomerdarium*, *C. queenslandicum*, *Chrysosporium* state of *Thielavia sepedonium*, *C. tropicum*, *Microsporium cookei*, *M. gypseum*, *Myceliophthora* anamorph of *Corynascus novoguineensis*, *M. vellera* and *Trichophyton terrestre* from sewage sludge samples from Upper Egypt. Similarly, from the sediment samples collected from the Shatt Al-Arab River, and its creeks yielded *Aphanoascus fulvescens*, *A. durus*, *Chrysosporium crassitunicatum*, *C. keratinophilum*, *C. tropicum*, *M. fulvum*,

*M. gypseum* and *T. verrucosum* (Abdullah and Hassan 1995). In other study, sewage sludge samples collected from seven wastewater treatment plants in Sari city, Mazandaran Province, Islamic Republic of Iran yielded *Microsporium gypseum*, *Chrysosporium* spp. and *Geotrichum* spp. using the hair-baiting technique (Hedayati and Mirzakhani 2009). Ulfing et al. (2006) observed that there was a significant increase in the population of actidione-resistant keratinophilic fungi in the sludge during open-air drying and change in the numbers. Occurrence of these fungi in sewage slug/sediments can be a source of infection to man and animals (Kushwaha 2014).

## Cold Desert

Ladakh “land of high passes” in Karakoram mountain ranges in the Indian state of Jammu and Kashmir is the highest plateau with height of 3000 ft and is situated between latitudes 30°N–36°N and longitudes 76°E–79°E. The temperature in this area ranges from 3–35 °C in summer to –20 to –45 °C in winter. *Amauroascus kuehnii*, *Aphanoascus keratinophilus*, *A. terreus*, *Auxarthron alboluteum*, *A. conjugatum*, *Chrysosporium articulatum*, *C. minutisporosum*, *C. mephiticum*, *C. siglerae*, *Chrysosporium* sp. *C. tropicum*, *C. submersum*, *C. state of Ctenomyces serratus*, *Geomyces pannorum* were isolated from the soils of cold desert of Ladakh. The samples were collected from places like Pangong Tso, Chang La, Durbuk, Khardung La, Tangste, Lukung, Magnetic Hill, Phey village, Leh and Nimmu and were from pastures, glacier, roadside, bank of lake, uncultivated soil, cultivated soil, river bank and roadside (Deshmukh et al. 2010). *Chrysosporium inops*, *C. merdarium*, *C. queenslandicum*, *Chrysosporium* anamorph of *Gymnoascus demonbreunii* along with other fungi were isolated from the soils collected from Khardung (14,738 ft) (Kotwal and Sumbali 2011, 2014).

## Antarctic Environment

Antarctica is the coldest, windiest and the driest continent of the Earth, located at the South Pole. In Antarctic environment, the temperature in winter is as low as –63 °C and winter mean temperatures are –57 °C and lower. The temperature in summer is unlikely to be warmer than –18 °C. Low temperatures, high aridity, low and sporadic availability of nutrients are the major stress factors. In such extreme environment, fungi and bacteria can grow because of their oligotrophic nature (Parkinson et al. 1989). *Geomyces pannorum*, *Malbranchea gypsea*, *Malbranchea* sp, *Microsporium gypseum*, *M. megellanicum*, *Trichophyton mentagrophytes* and *T. terrestre* along with other fungi have been reported from Antarctica (Caretta and Piontelli 1977; Mercantini et al. 1989b; Mario Comerio and Mac Cormack 2004).

Keratinophilic fungi were reported from the dust samples collected in various rooms on the Italian scientist-base and from soil in close proximity to the base of Antarctica. The keratinophilic fungi isolated were *Malbranchea gypsea*,

*T. mentagrophytes*, *Aphanoascus fulvescens*, *C. carmichaelii*, *Geomyces pannorum* var *pannorum* and *G. pannorum* var *vinaceus* (Mercantini et al. 1993). Keratinophilic fungi found in polar region might have been tuned to the environmental conditions and adapted to lifecycle, genetic and physiological modifications.

## Wildlife Sanctuary

In the wildlife sanctuary, the keratinous material, viz. hair and feathers, are added to the environment and keratinophiles survive on these substrates. Deshmukh (2002a) recorded *Arthroderma simii*, *Chrysosporium indicum*, *C. keratinophilum*, *C. pannicola*, *Gymnoascella hylinospora*, *Malbranchea aurantiaca*, *Microsporium gypseum* complex and *Trichophyton terrestre* in the soils collected from “The Periyar Wildlife Sanctuary” (Kerala, India). The sanctuary is known for rich fauna including elephants, tigers, bison and spotted deer. The occurrence of these fungi in “The Periyar Wildlife Sanctuary” can be due to the presence of animals and birds with less human interference (Deshmukh 2002b). Deshmukh and Verekar (2006a) isolated *Chrysosporium queenslandicum*, *C. xerophilum* and *Malbranchea gypsea* from the soils of Pin Valley National Park (Himachal Pradesh, India) famous for herds of Asiatic ibex (*Capra ibex*), Snow Leopard (*Uncia uncia*) and Himalayan blue sheep (*Pseudois nayaur*). Their occurrence is an indication of their adaptation to cold climate. While screening soils of Sanjay Gandhi National Park Mumbai, Deshmukh and Verekar (2014a) reported the presence *Aphanoascus durus*, *Arthroderma corniculatum*, *Auxarthron umbrinum*, *Chrysosporium evolceanui*, *C. indicum*, *C. tropicum*, *C. zonatum*, *Chrysosporium* state of *Arthroderma tuberculatum*, *Chrysosporium* state of *Ctenomyces serratus*, *Gymnascella dankaliensis*, *Microsporium gypseum*, *Myriodontium keratinophilum* and *Trichophyton mentagrophytes*. Deshmukh and Verekar (2014b) also reported *Aphanoascus durus*, *A. fulvescens*, *Arthrographis kale*, *Auxarthron conjugatum*, *Chrysosporium indicum*, *C. tropicum*, *C. zonatum*, *Chrysosporium* state of *Ctenomyces serratus*, *Microsporium gypseum* and *Trichophyton mentagrophytes* from the soils of Gir Forest National Park and Wildlife Sanctuary, Gujarat (India), known for Asiatic Lions (*Panthera leo persica*). Similarly, a new fungus *Auxarthronopsis bandhavgarhensis* was isolated from Bandhavgarh National Park situated in the central India state Madhya Pradesh (Sharma et al. 2013). The occurrence of these fungi in these national parks indicates that these fungi are associated with the birds and animals of the national parks.

## Poultry Farm

Poultry farm serves as a reservoir of keratinophilic and toxigenic fungi. There are reports on the occurrence of these fungi in poultry environment which include birds, cages, transporting trucks and dumping grounds. Various researchers have reported elevated occurrence of keratinophilic fungi in poultry farm soils

(Jain et al. 1985; Deshmukh 1999; Kaul and Sumbali 2000a; Anbu et al. 2004), which are neutral to weakly alkaline in nature and rich in organic matter. A high content of organic carbon, nitrogen, phosphorus, potassium, magnesium, calcium and iron is present in this habitat (Kaul and Sumbali 1998–99). Deshmukh (1999) recovered *C. indicum*, *C. lobatum* and *Microsporium gypseum* from poultry farm soil while surveying keratinophilic fungi from Mumbai and its vicinity. *Chrysosporium indicum*, *C. lucknowense*, *C. pannicola*, *C. queenslandicum*, *Chrysosporium I*, *Chrysosporium II*, *C. tropicum*, *C. zonatum*, *C. state of Arthroderma tuberculatum*, *Geomyces pannorum*, *Malbranchea pulchella*, *Microsporium gallinae*, *Trichophyton mentagrophytes* and *T. simii* were isolated from poultry farm soils from Bilaspur district of Chhattisgarh (India) (Deshmukh and Shukala 2000). Kaul and Sumbali (2000a) recorded very high per cent of keratinophilic fungi which were attributed to higher influx of poultry droppings and other remains (feathers and claws) in this soil. Keratinophilic fungi were also recorded from poultry farm from Namakkal and feather dumping sites from Chennai. The isolated fungi were *M. gypseum*, *Trichophyton mentagrophytes*, *Chrysosporium keratinophilum*, *Chrysosporium state of Arthroderma tuberculatum*, *Geomyces pannorum* (Anbu et al. 2004). Kaul and Sumbali (2000a, b) isolated *C. keratinophilum*, *C. queenslandicum*, *C. tropicum*, *C. indicum* and *Malbranchea chrysosporoidea* from feathers of poultry birds (*Gallus domesticus*). They also found *C. keratinophilum*, *C. queenslandicum*, *C. tropicum*, *C. pannorum* and *Malbranchea flava* from soils of poultry farm. The study indicates that colonization of these fungi on bird feathers is because they spent more time on ground.

### Piggery Soils

Fifteen different keratinophilic fungi were reported from the soil samples collected from the piggeries of Ranchi, Jharkhand (India) (Kumar et al. 2012). The reported fungi were *Aspergillus niger*, *A. terreus*, *A. flavus*, *Penicillium chrysogenum*, *Penicillium* sp., *Alternaria alternata*, *Fusarium oxysporum*, *F. solani*, *Trichoderma harzianum*, *T. reesei*, *T. viride*, *Curvularia lunata*, *Chrysosporium* sp. *Mucor pusillus* and *Rhizopus stolonifer*. The majority of them were secondary colonizer on keratin baits. More attention is needed to isolate the true species of keratinophiles from this environment.

### House Dust

*Chrysosporium carmichaelii*, *C. evolceanui*, *C. indicum*, *C. keratinophilum*, *C. merdarium*, *C. pannicola*, *C. queenslandicum* and *C. tropicum* and other fungi were isolated from house dust of Kanpur (Nigam and Kushwaha 1990, 1993). From the dust samples collected from hospitals and houses in Kanpur, *Acremonium*

*implicatum*, *A. strictum*, *Aphanoascus fulvescens*, *Arthroderma simii*, *C. queenslandicum*, *C. indicum*, *C. pannicola*, *C. tropicum*, *Ctenomyces serratus*, *Gymnoascus reessii*, *Malbranchea fulva*, *Malbranchea pulchella*, *Microsporum gypseum*, *Microsporum cookie*, *M. fulvum*, *Paecilomyces lilacinum*, *Penicillium expansum*, *Trichophyton mentagrophytes* and *T. terrestre* were recorded (Singh et al. 2009a, b). In hospitals, *C. serratus* was less prevalent while the *A. simii* was the most. In houses, *C. queenslandicum* was less prevalent and *C. tropicum* the most (Singh et al. 2009a, b). While surveying keratinophilic fungi from Jaipur, Jain and Sharma (2011) reported *Trichophyton terrestre* and *C. tropicum* from house dust. Similarly, Vidyasagar et al. (2005) recovered *Microsporum gypseum*, *Chrysosporium keratinophilum*, *Trichophyton mentagrophytes*, *M. nanum* and *C. tropicum* from corridor dust of hospitals and soils of public places from Gulbarga in Karnataka (Vidyasagar et al. 2005). These data show the capability of the long-term existence of pathogenic fungi in the soil of indoor environments and is the main link in the human circulation of these pathogens.

*Chrysosporium asperatum*, *C. state* of *Arthroderma tuberculatum*, *C. indicum*, *C. inops*, *C. keratinophilum*, *C. merdarium*, *C. pannorum*, *C. queenslandicum*, *C. tropicum* and *C. xerophilum* along with *Trichophyton verrucosum* and *Trichophyton* sp. were isolated from air dust particles from Egypt (Abdel-Hafez et al. 1990a). Moubasher et al. (1990) reported *Chrysosporium asperatum*, *C. indicum*, *C. keratinophilum*, *C. merdarium*, *C. pannorum* and *C. tropicum* from the atmosphere of hay or winnow sites and from combine harvester wheat and sorghum air dust.

*Epidermophyton floccosum*, *M. canis*, *M. gypseum* and *T. mentagrophytes* along with species of *Chrysosporium* were isolated from the dust of ferry boats of Italy. *C. pannorum* was the most prevalent species amongst *Chrysosporium*. In the same study, *E. floccosum*, *T. mentagrophytes*, *T. tonsurans*, *T. ajelloi*, *Trichophyton* spp., *M. canis* and *M. gypseum* and seven different species of *Chrysosporium* were isolated from the dust of railway cars; *C. pannorum* was the most numerous one amongst the *Chrysosporium* sp. (Mercantini et al. 1989a).

## Meteoritic Crater

Deshmukh and Verekar (2006b) reported *Aphanoascus durus*, *A. punsolae*, *Auxarthron kuehnii*, *C. indicum*, *C. tropicum*, *Chrysosporium* sp., *Chrysosporium* state of *Ctenomyces serratus* from Lonar meteorite crater in Maharashtra state (India). Lonar lake water is ten times saltier than drinking water (pH 10.5) and contains salts and minerals of sodium, chloride, carbonates, fluorides and bicarbonates. The area in and around is lush green with dense forest with numerous species of birds and animals. The occurrence of these fungi in such environment shows the addition of keratin material to the crater by birds and animals.

## Veterinary Clinic

*Microsporum canis*, *M. gypseum*, *T. ajelloi*, *T. mentagrophytes*, *T. terrestre*, *C. keratinophilum*, *C. pannorum*, *C. tropicum*, *Chrysosporium* sp., *C. state* of *Arthroderma tuberculatum* were isolated from the veterinary clinic (Mancianti and Papini 1996). Dermatophytes survives for longer period in dormant form in the clinic and clinical materials is the matter of concern. The clinical materials can come in the direct contact and be the means of transmission of dermatophytes. The presence of mites on animals can be another source of transmission of these fungi in veterinary clinics. Therefore, such clinics may represents sites where pets and human are exposed to the risk of infection of such pathogenic fungi.

## Coastal Habitats

The coastal areas are an environment for migratory birds and burrowing animals. Occurrence of these fungi in such coastal soils supported the view that this habitat is a rich source of keratinophilic fungi. Deshmukh (2002b) reported *Chrysosporium indicum*, *C. keratinophilum*, *C. tropicum*, *Chrysosporium* state of *Ctenomyces serratus*, *Microsporum gypseum* complex, *Trichophyton mentagrophytes* and *T. terrestre* from Kovalam beach, Kerala (India). Occurrence of keratinophilic fungi in saline areas may be attributed to the preference of keratin material in such habitats. Many investigators studied the effect of salinity on the growth and survival of fungi and demonstrated that keratinophilic fungi are common in saline environments (Kishimoto and Baker 1969; Deshmukh and Agrawal 1983b; Larrondo and Calvo 1989; Ulfig et al. 1997; Deshmukh 1999). Katiyar and Kushwaha (1997) isolated *C. keratinophilum*, *C. tropicum* and *Chrysosporium* sp. from sand of the Mediterranean Sea, which is poor in organic matter. Pugh and Mathison (1962) found maximum distribution of *Chrysosporium* in coastal soils due to enrichment by the droppings and fish debris, which favours more the growth of aleurosporic fungi. Relatively high density of these fungi in coastal soils might be due to the human activity and presence of marine birds and burrowing animals.

## Salt Pan Soils

Salt pans are very common in the coastal habitats and are part of the salt industry responsible for production of tons of salt around Mumbai and supplied to all over India. Seawater flows into the salt pans and brings keratinic material such as human hair, animal hair and wool fragments from blankets from neighbouring villages during high tide. Moulded feathers from various migrating birds also constitute part of the keratinic material in salt pans. The formation of salt takes 3–4 months.

During that period decomposition of keratin by keratinophilic fungi and related dermatophytes takes place. Deshmukh (2004a) reported *Chrysosporium indicum*, *Microsporium gypseum* complex, *C. tropicum*, *Chrysosporium* state of *Ctenomyces serratus*, *C. fluviale*, *Malbranchea aurantiaca*, *Trichophyton mentagrophytes*, *T. terrestre*, *Malbranchea* sp. and *Uncinocarpus reesii* from the soils around salt pans in Mumbai. This investigation indicates that soil of salt pans and surrounding areas provides an unusual ecological environment for keratinophilic fungi and related dermatophytes.

## Animals

Keratinophilic fungi are reported from hairs of various animals which include cows, donkeys, rabbits, cats, dogs, goats and wild boars. The most frequently isolated species are *Trichophyton mentagrophytes*, *T. verrucosum*, *T. ajelloi*, *T. terrestre*, *Microsporium gypseum*, *M. nanum*, *M. canis*, *Arthroderma cuniculi*, *A. curreyi* and a number of species of *Chrysosporium* (Ali-Shtayeh et al. 1988, 1989; Abdel-Hafez et al. 1990b; Al-Musallam 1990; Mancianti et al. 1997; Guzman-Chavez et al. 2000). Mite *Tyrophagus putrescentiae* was found associated with *M. canis* and may be responsible for transmitting fungi amongst animals (Caretta et al. 1989). The occurrence of these fungi on these animals can be a risk of dermatophytic infections to man and animals.

## Birds and Its Environment

The birds act as reservoirs of zoophilic keratinophiles and transport them from one place to another. It is thought that some fungal association with birds are species specific. These fungi occur in nests and can be transmitted from parents to offspring (Pugh 1972). There are several reports of occurrence of these fungi from birds and its environment (Sur and Ghosh 1980; Dixit and Kushwaha 1991; Sarangi and Ghosh 1991; Deshmukh 2004b). The most frequently isolated species include *Chrysosporium evolceanui*, *C. indicum*, *C. tropicum*, *Microsporium gypseum*, *M. fulvum*, *Microsporium* sp., *Trichophyton mentagrophytes*, *Malbranchea pulchella*, *Aphanoascus reticulisporus*, *Gymnoascoideus petalosporus*, *Malbranchea fulva*, *Pseudoarachniotus flavoluteus*, *P. roseus*, *R. hyalinospora*, *Rollandina capitata*, *Myriodontium keratinophilum*. While surveying keratinophilic fungi from different migratory bird *Chrysosporium keratinophilum*, *C. tropicum*, *C. merdarium*, *C. luteum*, *C. parvum*, *C. pruinosum*, *C. asperatum*, *Scopulariopsis* sp., *Trichophyton terrestre*, *Arthroderma tuberculatum*, *Sepedonium* spp. were isolated from 10 birds (Budgerigar, Ring neck, Lovebird, Pigeon, Alexandrian parrot, Amazon parrot, African grey, Quail, Duck and Chicken) from different countries coming to Bahrain (Mandeel et al. 2011). Similarly, *Auxarthron conjugatum*, *Chrysosporium fluviale*, *C. indicum*, *C. tropicum*, *Chrysosporium* state of *Ctenomyces serratus*, *Gymnoascus petalosporus* and *Microsporium gypseum* complex

were recorded from various sites in the vicinity of Vedanthangal Water Bird Sanctuary. From this study, we can conclude that migratory birds can be a mode of transport of variety of keratinophiles from one place to another (Deshmukh and Verekar 2011b).

## Pathogenic Fungi

Species of *Chrysosporium* are reports from immuno-compromised patients causing various types of mycoses (Anstead et al. 2012). From a female in Chiba and from a male in Kyushu, *Chrysosporium zonatum* was isolated from bronchial lavage (Sigler et al. 1998). Roilides et al. (1999) reported *Chrysosporium zonatum* as the causative agent of chronic granulomatous disease. *Myriodontium keratinophilum* teleomorph of *Neoarachnotheca keratinophila* was found to cause sinusitis (Maran et al. 1985). There was a report of isolation of *Gymnascella dankaliensis* from superficial infections in human (De Hoog and Guarro 1995). Other species of *Gymnascella*, i.e. *G. hyalinospora* was reported from invasive pulmonary infection in a patient with acute myelogenous leukaemia (Iwen et al. 2000). Lysková (2007) reported *Chrysosporium queenslandicum*, *C. sulfureum*, *C. tropicum*, *Malbranchea pulchella*, *Myriodontium keratinophilum* from infections of the skin and nails of patients in the Moravian-Silesian Region of Czech Republic. *Geomyces pannorum* var. *pannorum* was isolated from superficial infection of the skin of a healthy man (Gianni et al. 2003). Zelenková (2006) reported *Chrysosporium pannorum* (Link) Hughes from finger nails of male and female patients from Slovak Republic. Saidi et al. (1994) reported *Chrysosporium tropicum* from the comb lesion in two breeds of chicken in India.

There are reports of infection of *Chrysosporium* species in multiple reptile species. *Chrysosporium guarroi* was isolated from pet green iguanas (*Iguana iguana*) from different areas of Spain (Abarca et al. 2010) and Turkey (Kahraman et al. 2015). *Chrysosporium queenslandicum* was isolated from a garter snake (Vissiennon et al. 1999). In the review by Paré and Jacobson (2007), it is reported that *Chrysosporium keratinophilum*, *C. tropicum* and *Chrysosporium* spp. can be a causal agents of cutaneous and systemic mycoses in reptile species. *Chrysosporium* anamorph of *Nannizziopsis vriesii* (CANV) was found to be a causal agent of dermatitis in multiple reptile species such as chameleons (Paré et al. 1997), similarly, it was identified from snakes (Bertelsen et al. 2005; Nichols et al. 1999), salt-water crocodiles (Thomas et al. 2002), bearded dragons (Bowman et al. 2007; Hedley et al. 2010), green iguanas (*Iguana iguana*) (Han et al. 2010) and girdled lizards (Hellebuyck et al. 2010). A *Chrysosporium* spp. related to *Nannizziopsis vriesii* was responsible for causing skin lesions in a pet bearded dragon (Abarca et al. 2009). Mycotic granuloma of a black rat snake was caused by *Chrysosporium ophioidicola* (Rajeev et al. 2009). These reports indicate that the species of *Chrysosporium* may be regarded as opportunistic pathogens.

## Biodegradation of Keratin

The invasion of hair by dermatophytes has been investigated with light and electron microscopy under natural and experimental conditions. English (1963) described the stages by which detached hair is attacked by keratinophilic fungi in following sequence (a) Cuticle lifting, (b) Cortical erosion, (c) Production of penetrating organism and (d) Colonization of medulla. Kanbe and Tanaka (1982) also recognized these stages, but they overlap one another during the process of infection with *M. gypseum*. Deshmukh and Agrawal (1982, 1985) studied the in vitro degradation of human hair by various soils inhabiting keratinophilic fungi. They observed that the in vitro breakdown of hair is characterized by the release of protein, peptides, amino acid and resulted in the marked alkalinization of the medium. Microscopic examination showed extensive hair damage and extensive rupturing of the hair cuticle. It was hypothesized that the reducing agent responsible for this process is sulphate, which is produced by oxidation of cysteine during the process of keratinolysis in dermatophytes (Kunert 1972). The enzyme responsible for production of sulphite from cystine/cysteine is cysteine dioxygenase (CDO), which reduces and degrade keratin. CDO is responsible for keratinolysis which is an important part in dermatophyte pathogenesis. CDO along with the sulphite transporter SSU1 is probably one of the most important dermatophyte virulence factors (Grumbt et al. 2013; Kasperova et al. 2013). Huang et al. (2015) reported the production and characterization of keratinolytic protease produced by *Onygena corvine* and suggested that *O. corvine* can be used for bioconverting feather waste into high-value products.

## Bioactive Metabolites from Keratinophilic Fungi

A number of antimicrobial substances have been reported from *M. gypseum* and *Trichophyton violaceum*. Fusidic acid, penicillins, quinone antibiotics, gypsetin, 6 APA are some of the major antimicrobial compounds produced by *M. gypseum* (Uri et al. 1963; Elander et al. 1969; Shinohara et al. 1994). *T. violaceum* and *T. rubrum* are known to produce quinone antibiotics (Subrahmanyam 1980). *T. violaceum* produces vioxanthin and xanthomagnin possessing antimicrobial properties while *T. mentagrophytes* was found to produce antibiotics of penicillin group. *Epidermophyton floccosum*, an anthropophilic dermatophyte is also known to synthesize floccosin, an antifungal and floccosic acid, an antibacterial compound (Blank et al. 1969). Some non-dermatophytic keratinophilic fungi are also known to produce certain antibiotics. Production of anthraquinones (questin and questinol) and asteric acid by *Chrysosporium merdarium* is reported by Haskins (1971). *C. indicum* produces L-Arginyl-D-allothreonyl-L-phenylalanine, an antifungal compound (Koenig et al. 1973). *C. pannorum* produces cryscandin, antibacterial and an anticandidal compound and pannorin, 3-hydroxy-e-methylglutaryl coenzyme, a reductase inhibitor (Yamashita et al. 1984; Ogawa et al. 1991). *Amauroascus niger* produces zaragozic acids, D and D2, which inhibits farnesyl transferase with IC<sub>50</sub> values of

100 nM, (Dufresne et al. 1993). *Malbranchea aurantiaca* produces 1-hydroxy-2-oxoeremophil-1(10), 7(11),8(9)-trien-12(8)-olide and penicillic acid which causes significant inhibition of radicle growth of *Amaranthus hypochondriacus* with  $IC_{50}$  values 6.57 and 3.86  $\mu$ M, respectively. In addition, 1-hydroxy-2-oxoeremophil-1(10), 7(11),8(9)-trien-12(8)-olide inhibited activation of the calmodulin-dependent enzyme cAMP phosphodiesterase ( $IC_{50}$  =10.2  $\mu$ M) (Martinez-Luis et al. 2005).

Compounds produced by other non-dermatophytic keratinophilic fungi such as *Arachinotus aureus*, *Arachinotus flavoluteous*, *Pseudoarachnietus roseus*, *Malbranchea* species and *Auxarthron umbrinum* with antimicrobial and antitumor properties include: aranorosin, aranorosinol A, aranorosinol B, aranochlor A and aranochlor B (Roy et al. 1988, 1992; Mukhopadhyay et al. 1998), malbranchin (Chiung et al. 1993) and rumbrin (Yamagishi et al. 1993). Rumbrin a cytoprotective substance was isolated from *Auxarthron umbrinum* (Yamagishi et al. 1993; Alvi and Rabenstein 2004). *Malbranchea cinnamomea* is known to produce malbranchin, a quinone antibiotic with both antimicrobial and cytotoxic activity (Chiung et al. 1993). Premabai and Narsimharao (1966) isolated malbranchin A and B from *Malbranchea* sp which possesses antimicrobial properties.

The production of antiviral substances, i.e. acetyl aranotin, aporaratrotin and aranotin A by *Arachnietus aureus* and antifungal compounds such as aranorosin, aranorosinol A and aranorosinol B by *Pseudoarachnietus* and L-Arginyl-D-allo-threonil-L-phenylalanine by *Chrysosporium indicum* are of great significance in pharmaceutical industries as a lead molecule for development of drugs. The overall metabolic potential of keratinophilic fungi is immense because of their specific nature. Keratinophilic fungi if explored extensively for metabolite production can be a novel source of many promising molecules of medical, biotechnological and agrochemical utility.

## **Keratinophilic Fungi for Green Synthesis of Nanoparticles**

The keratinophilic fungi and related dermatophytes are also known to synthesize silver nanoparticles. It is reported that silver nanoparticles (SNPs) display effective antimicrobial properties (Panacek et al. 2006). The biosynthesis of SNP using three dermatophytic fungi, i.e. *Trichophyton rubrum*, *T. mentagrophytes* and *Microsporum canis* was reported by Moazeni et al. (2012). It was also found that species within the genus of the fungi have the capability to synthesize SNP with different efficiency and physical property (size and shape). Similarly, uniform, spherical SNP in the range of 20–50 nm were synthesized by *C. tropicum* (Soni and Prakash 2011).

## Role of Keratinophilic Fungi in Petroleum Hydrocarbon Degradation

Keratinolytic fungi are found in the biopile at the refinery, with *Trichophyton ajelloi* as the most dominant species which may be due to the presence of human population in the vicinity and their activity (Ulfig et al. 2003). The keratinolytic and keratinophilic fungi like *Microsporum* sp., *Trichophyton* sp. and *Chrysosporium* sp. are reported in petroleum hydrocarbon degradation (Davies and Westlake 1979; Ulfig 2000). Biopile soil does not favour the growth of dermatophyte and *Trichophyton ajelloi*, which is a predominating species rarely cause infection (de Hoog and Guarro 1995); therefore, the biopile bioremediation process for petroleum hydrocarbon degradation can be regarded as safe from the fungal epidemiological point of view.

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## Outlook

Occurrence of these fungi has been studied in many environments including various types of soil, birds, bird nests and animal farms. Besides, we do not yet know how many novel strains of keratinophilic fungi are hidden in other habitats with varied physical and chemical environmental conditions and how many of them are pathogenic to both man and animals. The ecological factors responsible for the distribution of fungi and various conditions for the formation of anamorph and teleomorph need more attention. Hence, a systemic distribution pattern of dermatophytes and related keratinophilic fungi from unexplored areas such as heated and self-heated materials, environments with low and extreme pH values, high salt and solute concentrations needs attention.

It more than 65 years, scientists are working in this field and isolated keratinophilic fungi from soil, birds and their environment, healthy animal skin and disease specimens but are not available as in India as reference. The availability of these fungi as specimens will definitely be of immense value to younger scientists with new ideas and the ability to get much better results using biotechnological methods. It is of high importance to have culture collections that carry the standard strains and biodiverse isolates. Taxonomic identification by both classical criteria and molecular biological tools is a must in such culture collection centres.

It is evident that keratinophilic fungi have been prolific producers of numbers of important pharmaceutical compounds and novel skeletons. This makes it very important to have a systematic classification of the different active molecules identified from various species related to their ecological prevalence. This group of fungi is known to degrade keratinic material into peptides and amino acids by the action of enzyme keratinase. Keratinase is used industrially to remove hair from a hide in the preparation of quality leather. Certain genetically modified strains are

required which can decompose tons of waste keratin that generates into peptides and amino acids. The hydrolytic products can be used as poultry and animal feed whereas the enzyme keratinase can be used in leather industry.

The ability of dermatophytes and related keratinophilic fungi can be explored to produce metallic nanoparticles which can have various pharmaceutical and agriculture applications. Keratinophilic fungi have the ability to remove petroleum hydrocarbons and can be used as cost-effective way to naturally remediate petroleum-contaminated soils.

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## References

- Abarca ML, Castellá G, Martorell J, Cabañes FJ (2010) *Chrysosporium guarroi* sp. nov. a new emerging pathogen of pet green iguanas (*Iguana iguana*). *Med Mycol* 48(2):365–372
- Abarca ML, Martorell J, Castellá G, Ramis A, Cabañes FJ (2009) Dermatophytosis in a pet inland bearded dragon (*Pogona vitticeps*) caused by a *Chrysosporium* species related to *Nannizziopsis vriesii*. *Vet Dermatol* 20:295–299
- Abdel-Hafez All, El-Sharouny HMM (1987) Seasonal fluctuations of fungi in Egyptian soil receiving city sewage effluents. *Cryptogamia* 8:235–249
- Abdel-Hafez SI, Moubasher AH, Barakat A (1990a) Keratinophilic fungi and other moulds associated with air dust particles from Egypt. *Folia Microbiol* 35(4):311–325
- Abdel-Hafez AI, Moharram AM, Abdel-Gawad KM (1990b) Survey of keratinophilic and saprobic fungi in the cloven-hooves and horns of goats and sheep from Egypt. *J Basic Microbiol* 30(1):13–20
- Abdel-Hafez AI, El-Sharouny HM (1990) The occurrence of keratinophilic fungi in sewage sludge from Egypt. *J Basic Microbiol* 30(2):73–79
- Abdullah SK, Hassan DA (1995) Isolation of dermatophytes and other keratinophilic fungi from surface sediments of the Shatt Al-Arab River and its creeks at Basrah, Iraq. *Mycoses* 38(3–4):163–166
- Agut M, Bayo M, Larrondo J, Calvo MA (1995) Keratinophilic fungi from soil of Brittany, France. *Mycopathologia* 129:81–82
- Al-Musallam AA (1989) Distribution of keratinophilic fungi in desert soil of Kuwait. *Mycoses* 32(6):296–302
- Al-Musallam AA (1990) Distribution of keratinophilic fungi in animal folds in Kuwait. *Mycopathologia* 112(2):65–70
- Ali-Shtayeh MS (1989) Keratinophilic fungi of school playgrounds in the Nablus area, West Bank of Jordan. *Mycopathologia* 106(2):103–108
- Ali-Shtayeh MS, Khaleel TKh, Jamous RM (2002) Ecology of dermatophytes and other keratinophilic fungi in swimming pools and polluted and unpolluted streams. *Mycopathologia* 156(3):193–205
- Ali-Shtayeh MS, Arda HM, Hassouna M, Shaheen SF (1988) Keratinophilic fungi on the hair of cows, donkeys, rabbits, cats, and dogs from the West Bank of Jordan. *Mycopathologia* 104(2):109–121
- Ali-Shtayeh MS, Arda HM, Hassouna M, Shaheen SF (1989) Keratinophilic fungi on sheep hairs from the West Bank of Jordan. *Mycopathologia* 106(2):95–101
- Alvi KA, Rabenstein J (2004) Auxarthrol A and auxarthrol B: two new tetrahydroanthraquinones from *Auxarthron umbrinum*. *J Ind Microbiol Biotechnol* 31(1):11–15
- Anane S (2012) Epidemiological investigation of keratinophilic fungi from soils of Djerba (Tunisia). *J Mycol Med* 22(3):225–229

- Anane S, Al-Yasiri MH, Normand AC, Ranque S (2015) Distribution of keratinophilic fungi in soil across Tunisia: a descriptive study and review of the literature. *Mycopathologia* 180(1): 61–68
- Anbu P, Hilda A, Gopinath SC (2004) Keratinophilic fungi of a poultry farm and feather dumping soil in Tamil Nadu, India. *Mycopathologia* 158(3):303–309
- Anstead GM, Sutton DA, Graybill JR (2012) Adiaspiromycosis causing respiratory failure and a review of human infections due to *Emmonsia* and *Chrysosporium* spp. *J Clin Microbiol* 50:1346–1354
- Bertelsen MF, Crawshaw GJ, Sigler L, Smith DA (2005) Fatal cutaneous mycosis in tentacled snakes (*Erpeton tentaculatum*) caused by the *Chrysosporium* anamorph of *Nannizziopsis vriesii*. *J Zoo Wildl Med* 36:82–87
- Blank F, Buxtorf C, Chin O, Just G, Tudor JL (1969) Metabolites of pathogenic fungi: VIII floccosin and floccosic acid, two metabolites from *Epidermophyton floccosum* (Harz) Langeron and Milochevitch 1930. *Can J Chem* 47:1561–1570
- Bowman MR, Paré JA, Sigler L, Naeser JP, Sladky KK, Hanley CS, Helmer P, Phillips LA, Brower A, Porter R (2007) Deep fungal dermatitis in three inland bearded dragons (*Pogona vitticeps*) caused by *Chrysosporium* anamorph of *Nannizziopsis vriesii*. *Med Mycol* 45:371–376
- Calvo A, Vidal M, Guarro J (1984) Keratinophilic fungi from urban soils of Barcelona, Spain. *Mycopathologia* 85:145–147
- Caretta G, Piontelli E (1977) *Microsporium magellanicum* and *Cunninghamella Antarctica*, new species isolated from Australia and Antarctic soil of Chile. *Sabouraudia* 15(1):1–10
- Caretta G, Mancianti F, Ajello L (1989) Dermatophytes and keratinophilic fungi in cats and dogs. *Mycoses* 32(12):620–626
- Caretta G, Ajello L, Padhye AA (1990) The occurrence of *Arthroderma gloriae*, a geophilic, keratinophilic ascomycete, Italy. *J Med Vet Mycol* 28(2):99–102
- Chiung YM, Fujita T, Nakagawa M, Nozaki H, Chen GY, Chen ZC, Nakayama M (1993) A novel quinone antibiotic from *Malbranchea cinnamomea* TAIM 13T54. *J Antibiot* 46:1819–1826
- Davies JS, Westlake DWS (1979) Crude oil utilization by fungi. *Can J Microbiol* 25(2):146–156
- De Hoog GS, Guarro J (1995) Atlas of clinical fungi. Centraalbureau voor Schimmelcultures. Baarn, The Netherlands
- Deshmukh SK (1999) Keratinophilic fungi isolated from soils of Mumbai, India. *Mycopathologia* 146:115–116
- Deshmukh SK (2002a) Incidence of dermatophytes and other keratinophilic fungi in the glacier bank soils of Kashmir valley (India). *Mycologist* 16(4):165–167
- Deshmukh SK (2002b) The incidence of dermatophytes and other keratinophilic fungi in the soils of Kerala (India). *Mycopathologia* 156(3):177–181
- Deshmukh SK (2004a) Isolation of dermatophytes and other keratinophilic fungi from the vicinity of salt pan soils of Mumbai, India. *Mycopathologia* 157(3):265–267
- Deshmukh SK (2004b) Keratinophilic fungi on feathers of pigeon in Maharashtra, India. *Mycoses* 47(5–6):213–215
- Deshmukh SK, Agrawal SC (1982) In-vitro degradation of human hair by some keratinophilic fungi. *Mykosen* 25(8):454–458
- Deshmukh SK, Agrawal SC (1983a) Prevalence of dermatophytes and other keratinophilic fungi in soils of Madhya Pradesh (India). *Mykosen* 26:574–577
- Deshmukh SK, Agrawal SC (1983b) Isolation of keratinophilic fungi from coastal habitats of Goa (India). *Kavaka* 11:53–54
- Deshmukh SK, Agrawal SC (1985) Degradation of human hair by some dermatophytes and other keratinophilic fungi. *Mykosen* 28(9):463–466
- Deshmukh SK, Agrawal SC, Jain PC (2000) Isolation of dermatophytes and other keratinophilic fungi from soils of Mysore India. *Mycoses* 43(1–2):55–57
- Deshmukh SK, Shukala RV (2000–2001) Isolation of keratinophilic fungi from poultry farm soils of Chhattisgarh (India). *Kavaka* 28–29:55–58

- Deshmukh SK, Mandeel QA, Verekar SA (2008) Keratinophilic fungi from selected soils of Bahrain. *Mycopathologia* 165(3):143–147
- Deshmukh SK, Verekar SA (2006a) The occurrence of dermatophytes and other keratinophilic fungi from the soils of Himachal Pradesh (India). *Czech Mycol* 58:117–124
- Deshmukh SK, Verekar SA (2006b) Keratinophilic fungi from the vicinity of meteorite crater soils of Lonar (India). *Mycopathologia* 162(4):303–306
- Deshmukh SK, Verekar SA, Shrivastav A (2010) Prevalence of keratinophilic fungi in selected soils of Ladakh (India). *Nat Sci* 2(11):1147–1152
- Deshmukh SK, Verekar SA (2011a) Prevalence of keratinophilic fungi in ‘Usar’ soils of Uttar Pradesh, India. *Microbiol Res* 3:e15. <https://doi.org/10.4081/mr.2011.e15>
- Deshmukh SK, Verekar SA (2011b) The incidence of keratinophilic fungi from the soils of Vedanthangal Water Bird Sanctuary (India). *Mycoses* 54(6):487–490
- Deshmukh SK, Verekar SA (2012) Prevalence of keratinophilic fungi in public park soils of Mumbai, India. *Microbiol Res* 3:24–27. 3:e6 doi:<https://doi.org/10.4081/mr.2012.e6>
- Deshmukh SK, Verekar SA (2014a) Isolation of keratinophilic fungi from selected soils of Sanjay Gandhi National Park, Mumbai (India). *J Mycol Med* 24(4):319–327
- Deshmukh SK, Verekar SA (2014b) Isolation of keratinophilic fungi from selected soils of The Gir Forest National Park and Wildlife Sanctuary, Gujarat, (India). *Kavaka* 43:7–11
- Deshmukh SK, Verekar SA, Chavan YG (2017) Incidence of keratinophilic fungi from the selected soils of Kaziranga National Park Assam, (India). *Mycopathologia* 182:371–377
- Dey NC, Kakoti LM (1955) *Microsporium gypseum* in India. *J Indian Med Assoc* 25:160–164
- Dixit AK, Kushwaha RKS (1990) Keratinophilic fungi from Andaman Islands India. *Indian J Microbiol* 30:349–350
- Dixit AK, Kushwaha RKS (1991) The occurrence of keratinophilic fungi on Indian birds. *Folia Microbiol (Praha)* 36(4):383–386
- Dufresne C, Wilson KE, Singh SB, Zink DL, Bergstrom JD, Rew D, Polishook JD, Meinz M, Huang L, Silverman KC, Lingham RB, Mojena M, Cascales C, Peláez F, Gibbs JB (1993) Zaragozaic acids D and D2: potent inhibitors of squalene synthase and of Ras farnesyl-protein transferase. *J Nat Prod* 56(11):1923–1929
- Elander RP, Gordee RS, Wilgus RM, Gale RM (1969) Synthesis of antibiotic closely resembling fusidic acid by imperfect and perfect dermatophytes. *J Antibiot* 22:176–178
- Emmons CW, Binford CH, Utz JP, Kwon-Chung KJ (1977) *Medical mycology*, 3rd edn. Lea & Febiger, Philadelphia, USA
- English MP (1963) The saprophytic growth of keratinophilic fungi on keratin. *Sabouraudia* 2:115–130
- Filipello Marchisio V, Curetti D, Cassinelli C, Bordese C (1991) Keratinolytic and keratinophilic fungi in the soils of Papua New Guinea. *Mycopathologia* 115(2):113–119
- Ghosh GR, Bhatt S (2000) Keratinophilic fungi from Chilka lake-side soil Orissa (India). *Indian J Microbiol* 40:247–254
- Gianni C, Caretta G, Romano C (2003) Skin infection due to *Geomyces pannorum* var. *pannorum*. *Mycoses* 46(9–10):430–432
- Gopinath SCB, Anbu P, Lakshmi Priya T, Tang TH, Chen Y, Hashim U, Ruslinda R, Arshad MKM (2015) Biotechnological aspects and perspective of microbial keratinase production. *Biomed Res Int*. <https://doi.org/10.1155/2015/140726>
- Grumbt M, Monod M, Yamada T, Hertweck C, Kunert J, Staib P (2013) Keratin degradation by dermatophytes relies on cysteine dioxygenase and a sulfite efflux pump. *J Invest Dermatol* 133:1550–1555
- Gugnani HC, Sharma S, Wright K (2014) A preliminary study on the occurrence of keratinophilic fungi in soils of Jamaica. *Rev Inst Med Trop Sao Paulo* 56(3):231–234
- Gugnani HC, Sharma S, Gupta B, Gaddam S (2012) Prevalence of keratinophilic fungi in soils of St. Kitts and Nevis. *J Infect Developing Ctries* 6(4):347–351

- Guzman-Chavez RE, Segundo-Zaragoza C, Cervantes-Olivares RA, Tapia-Perez G (2000) The presence of keratinophilic fungi with special reference to dermatophytes on the hair coat of dogs and cats in México and Nezahualcoyotl cities. *Rev Latinoam Microbiol* 42(1):41–44
- Han J, Lee S, Na KJ (2010) Necrotizing dermatomycosis caused by *Chrysosporium* spp. in three captive green iguanas (*Iguana iguana*) in South Korea. *J Exot Pet Med* 19(3):240–244
- Haskins RH (1971) Production of yellow pigment anthroquinones [questin and questinol] and asteric acid. *Can J Microbiol* 17:1575–1579
- Hedayati MT, Mirzakhani M (2009) Survey of keratinophilic fungi in sewage sludge from wastewater treatment plants of Mazandaran, Islamic Republic of Iran. *East Mediterr Health J* 15(2):451–454
- Hedayati MT, Mohseni-Bandpi A, Moradi S (2004) A survey of the pathogenic fungi in soil samples of potted plants from Sari hospitals, Iran. *J Hosp Infect* 58(1):59–62
- Hedley J, Eatwell K, Hume L (2010) Necrotising fungal dermatitis in a group of bearded dragons (*Pogona vitticeps*). *Vet Rec* 166:464–465
- Hellebuyck T, Baert K, Pasmans F, Van Waeyenberghe L, Beernaert L, Chiers K, De Backer P, Haesebrouck F, Martel A (2010) Cutaneous hyalohyphomycosis in a girdled lizard (*Cordylus giganteus*) caused by the *Chrysosporium* anamorph of *Nannizziopsis vriesii* and successful treatment with voriconazole. *Vet Dermatol* 21:429–433
- Huang Y, Busk PK, Lange L (2015) Production and characterization of keratinolytic proteases produced by *Onygena corvina*. *Fungal Genom Biol* 4:119. <https://doi.org/10.4172/2165-8056.1000119>
- Iwen PC, Sigler L, Tarantolo S, Sutton DA, Rinaldi MG, Lackner RP, McCarthy DI, Hinrichs SH (2000) Pulmonary infection caused by *Gymnascella hyalinospora* in a patient with acute myelogenous leukemia. *J Clin Microbiol* 38:375–381
- Jain M, Shukla PK, Srivastava OP (1985) Keratinophilic fungi and dermatophytes in Lucknow soils with their global distribution. *Mykosen* 28:148–153
- Jain N, Sharma M (2011) Distribution of dermatophytes and other related fungi in Jaipur city, with particular reference to soil pH. *Mycoses* 54(1):52–58
- Javoreková S, Labuda R, Maková J, Novák J, Medo J, Majerčíková K (2012) Keratinophilic fungi isolated from soils of long-term fold-grazed, degraded pastures in national parks of Slovakia. *Mycopathologia* 174(3):239–245
- Kachuei R, Emami M, Naeimi B, Diba K (2012) Isolation of keratinophilic fungi from soil in Isfahan province, Iran. *J Mycol Med* 22(1):8–13
- Kahraman BB, Sığırcı BD, Metiner K, Ak S, Koenhemsı L, Erman M, Castellá G, Abarca ML (2015) Isolation of *Chrysosporium guarroi* in a Green Iguana (*Iguana iguana*), in Turkey. *J Exotic Pet Med*. <https://doi.org/10.1053/j.jepm.2015.08.007>
- Kanbe T, Tanaka K (1982) Ultrastructure of the invasion of human hair in vitro by the keratinophilic fungus *Microsporum gypseum*. *Infect Immun* 38:706–715
- Kasperova A, Kunert J, Raska M (2013) The possible role of dermatophyte cysteine dioxygenase in keratin degradation. *Med Mycol* 51(5):449–454
- Katiyar S, Kushwaha RKS (1997) Human hair invasion by keratinophilic fungi isolated from Mediterranean sea beach. *Nat Acad Sci Lett* 20:71–74
- Kaul S, Sumbali G (1998–1999) The impact of some ecological factors on the occurrence of poultry soil-inhabiting keratinophiles. *Mycopathologia*. 143(3):155–159
- Kaul S, Sumbali G (2000a) Keratinophilic fungi from poultry farm soils of Jammu, India. *Mycologist* 14:89–91
- Kaul S, Sumbali G (2000b) Keratinophilic fungi from feathers of Indian poultry birds. *Mycologist* 14:148–150
- Kishimoto RA, Baker GE (1969) Pathogenic and potentially pathogenic fungi isolated from beaches sands and selected soils of Oahu Hawaii. *Mycologia* 61:537–548
- Koenig WA, Loeffler W, Meyr W, Uhmman R (1973) L-Arginyl-D-Allothreonil-L-Phenylalanine, ein Aminosäure-Antagonist aus dem Pilz, Keratinophyton terreum. *Chem Bericht* 106:816

- Kotwal S, Sumbali G (2011) The incidence of myco-keratinophiles in cold arid soil at the high altitude khardung village of Ladakh, India. *J Mycol Plant Pathol* 41:72–76
- Kotwal S, Sumbali G (2014) Comparative analysis of keratinophilic fungi from the soils of Khardung and Khardung La (Ladakh), India. *Biolife* 2(4):1326–1331
- Kumar R, Mishra R, Maurya S, Sahu HB (2012) Prevalence of keratinophilic fungi in piggery soils of Jharkhand, India. *The Ecoscan* 1:93–98
- Kunert J (1972) Keratin decomposition by dermatophytes: evidence of the sulphitolysis of the protein. *Experientia* 28:1025–1026
- Kushwaha RKS (2014) Keratinophilic fungi from bottom sediments: a review. *Int J Pharm Biol Arch* 5(5):62–73
- Kushwaha RKS, Agrawal SC (1976) Some keratinophilic fungi and related dermatophytes from soils. *Proc Indian Nat Sci Acad* 42(B):102–110
- Larrondo JV, Calvo MA (1989) Fungal density in the sand of the Mediterranean coast beaches. *Mycopathologia* 108:185–193
- Lysková P (2007) Saprotrophic microscopic fungi and dermatophytes accompanying infections of the skin and nails of patients in the Moravian-Silesian Region (Czech Republic). *Czech Mycol* 59:125–137
- Mancianti F, Mignone W, Papini R (1997) Keratinophilic fungi from coats of wild boars in Italy. *J Wildl Dis* 33(2):340–342
- Mancianti F, Papini R (1996) Isolation of keratinophilic fungi from the floors of private veterinary clinics in Italy. *Vet Res Commun* 20(2):161–166
- Mandeel Q, Nardoni S, Mancianti F (2011) Keratinophilic fungi on feathers of common clinically healthy birds in Bahrain. *Mycoses* 54(1):71–77
- Maran AGD, Kwong K, Milne LJR, Lam BD (1985) Frontal sinusitis caused by *Myriodontium keratinophilum*. *Brit Med J* 20:207
- Mario Comerio R, Mac Cormack W (2004) Some micromycetes isolated from spoiled food and soil in Argentine Antarctica. *Rev Iberoam Micol* 21(3):128–134 (Spanish)
- Martinez-Luis S, Gonzalez MC, Ulloa M, Mata R (2005) Phytotoxins from the fungus *Malbranchea aurantiaca*. *Phytochemistry* 66(9):1012–1026
- McAleer R (1980) Investigation of keratinophilic fungi from soils in western Australia a preliminary survey. *Mycopathologia* 72(3):155–165
- Mercantini R, Marsella R, Prignano G, Moretto D, Marmo W, Leonetto F, Fuga GC, Serio G (1989a) Isolation of keratinophilic fungi from the dust of ferry boats and trains in Italy. *Mycoses* 32(11):590–594
- Mercantini R, Marsella R, Cervellati MC (1989b) Keratinophilic fungi isolated from Antarctic soil. *Mycopathologia* 106(1):47–52
- Mercantini R, Marsella R, Moretto D, Finotti E (1993) Keratinophilic fungi in the antarctic environment. *Mycopathologia* 122(3):169–175
- Moazeni M, Rashidi N, Shahverdi AR, Noorbakhsh F, Rezaie S (2012) Extracellular production of silver nanoparticles by using three common species of dermatophytes: *Trichophyton rubrum*, *Trichophyton mentagrophytes* and *Microsporum canis*. *Iran Biomed J* 16(1):52–58
- Monga DP, Mohapatra LN (1980) A compilation of public reports of mycoses in animals in India. *Mycopathologia* 72:3–11
- Moubasher AH, Abdel-Hafez SI, Shoreit AA, Ismail MA (1990) Keratinophilic and other fungi isolated from combine harvester wheat and sorghum dusts and from the atmosphere of winnow sites in Egypt. *Folia Microbiol* 35(4):298–310
- Mukhopadhyay T, Bhat RG, Roy K, Vijayakumar EKS, Ganguli BN (1998) Aranochlor A and Aranochlor B, two new metabolites from *Pseudoarachniotus roseus*: production, isolation, structure elucidation and biological properties. *J Antibiot* 51:439–441
- Nichols DK, Weyant RS, Lamirande EW, Sigler L, Mason RT (1999) Fatal mycotic dermatitis in captive brown tree snakes (*Boiga irregularis*). *J Zoo Wildl Med* 30:111–118
- Nigam N (1987) Studies on *Chrysosporium* and allied fungi from soil. Ph.D. thesis, Kanpur University Kanpur, India

- Nigam N, Kushwaha RKS (1990) Occurrence of keratinophilic fungi with special reference to *Chrysosporium* species in India. *Sydowia* 42:200–208
- Nigam N, Kushwaha RKS (1993) Ecology of soil inhabiting keratinophilic fungi with special reference to *Chrysosporium*. In: Rai B, Arora DK, Dubey NK, Sharma PD (eds) *Fungal ecology and biotechnology*. Rastogi Publications, Meerut, India, pp 173–182
- Ogawa H, Hasumi K, Sakai K, Murakawa S, Endo A (1991) Pannorin, A new 3-hydroxy-3-methylglutaryl coenzyme a reductase inhibitor produced by *Chrysosporium pannorum*. *J Antibiot* 44:762–767
- Ogbonna CI, Pugh GJF (1987) Keratinophilic fungi from Nigerian soil. *Mycopathologia* 99 (2):115–118
- Padhye AA, Mishra SP, Thirumalachar MJ (1966) Occurrence of soil inhibiting dermatophytes and other keratinophilic fungi from soils in Poona. *Hindustan Antibiot Bull* 9:90–93
- Padhye AA, Pawar VH, Sukapure RS, Thirumalachar MJ (1967) Keratinophilic fungi from marine soils of Bombay India Part I. *Hindustan Antibiot Bull* 10:138–141
- Pakshir K, Ghiasi MR, Zomorodian K, Gharavi AR (2013) Isolation and molecular identification of keratinophilic fungi from public parks soil in Shiraz, Iran. *BioMed Res Int*. Article ID 619576, 5 p. <http://dx.doi.org/10.1155/2013/619576>
- Panacek A, Kvitek L, Pucek R, Kolář M, Večeřová R, Pizúrová N, Sharma VK, Tat'jana N, Radek Z (2006) Silver colloid nanoparticles: synthesis, characterization, and their antibacterial activity. *J Phys Chem B* 110(33):16248–16253
- Papini R, Mancianti F, Grassotti G, Cardini G (1998) Survey of keratinophilic fungi isolated from city park soils of Pisa, Italy. *Mycopathologia* 143(1):17–23
- Paré JA, Sigler L, Hunter DB, Summerbell RC, Smith DA, Machin KL (1997) Cutaneous mycoses in chameleons caused by the *Chrysosporium* anamorph of *Nannizziopsis vriesii* (Apinis) Currah. *J Zoo Wildl Med* 28:443–453
- Paré JA, Jacobson E (2007) Mycotic diseases of reptiles. In: Jacobson E (ed) *Infectious diseases and pathology of reptiles: a color atlas and text*. CRC Press, Boca Raton, FL, pp 527–570
- Parkinson SM, Wainwright M, Killham K (1989) Observations on oligotrophic growth of fungi on silica gel. *Mycol. Res.* 93:529–534
- Premabai M, Narsimharao PL (1966) Thermophilic microorganisms part ii fermentation characteristics of *Malbranchea pulchella*. *Indian J Biochem* 3:172–179
- Pugh GJF (1972) The contamination of birds feathers by fungi. *IBIS Int J Avian Sci* 114:172–177
- Pugh GJF, Mathison GE (1962) Studies on fungi in coastal soils. III. An ecological survey of keratinophilic fungi. *Trans Br Mycol Soc* 45:567–572
- Rajeev S, Sutton DA, Wickes BL, Miller DL, Giri D, Van Meter M, Thompson EH, Rinaldi MG, Romanelli AM, Cano JF, Guarro J (2009) Isolation and characterization of a new fungal species, *Chrysosporium ophioidicola*, from a mycotic granuloma of a black rat snake (*Elaphe obsoleta obsoleta*). *J Clin Microbiol* 47(4):1264–1268
- Ramesh VM, Hilda A (1998–1999) Incidence of keratinophilic fungi in the soil of primary schools and public parks of Madras City, India. *Mycopathologia* 143(3):139–145
- Randhawa HS, Sandhu RS (1965) A survey of soil inhabiting dermatophytes and related keratinophilic fungi of India. *Sabouraudia* 4:71–79
- Roilides E, Sigler L, Bibashi E, Katsifa H, Flaris N, Panteliadis C (1999) Disseminated infection due to *Chrysosporium zonatum* in a patient with the chronic granulomatous disease and review of non-aspergillus fungal infection in patients with this disease. *J Clin Microbiol* 37:18–25
- Roy K, Ghosh GR, Dutta SK (1972) Keratinophilic fungi and prevalence of dermatomycoses in Orissa, India. *Sabouraudia* 10:218–229
- Roy K, Mukhopadhyay T, Reddy GCS, Desikan KR, Rupp RH, Ganguli BN (1988) Aranorosin, a novel antibiotic from *Pseudoarachinotus roseus*. *J Antibiot* 41:1780–1784
- Roy K, Vijayakumar EKS, Mukhopadhyay T, Chatterjee S, Bhat RG, Blumbach J, Ganguli BN (1992) Aranorosinol A and aranorosinol B, two new metabolites from *pseudoarachinotus roseus*: production, isolation, structure elucidation and biological properties. *J Antibiot* 45:1592–1598

- Saidi SA, Bhatt S, Richard JL, Sikdar A, Ghosh GR (1994) *Chrysosporium tropicum* as a probable cause of mycoses of poultry in India. *Mycopathologia* 125:143–147
- Sarangi S, Ghosh GR (1991) Survey of keratinophilic fungi inhabiting *Passer domesticus* in two districts of Orissa India. *Mycopathologia* 114:109–116
- Sarmiento MM, Mangiaterra M, Bojanich MV, Basualdo JA, Giusiano G (2015) Keratinophilic fungi in soils of parks of Corrientes city, Argentina. *Rev Iberoam Micol.* pii: S1130 1406 (15) 00035–2
- Sharma R, Gräser Y, Singh SK (2013) Auxarthronopsis, a new genus of onygenales isolated from the vicinity of Bandhavgarh National Park, India. *IMA Fungus* 4(1):89–102
- Shinohara C, Hasumi K, Takei Y, Endo A (1994) Gypsetin, a new inhibitor of Acyl-CoA: cholesterol acyltransferase produced by *Nannizzia gypsea* var *incurvata* IFO 9228 I fermentation, isolation, physico-chemical properties and biological activity. *J Antibiot* 47:163–167
- Shrivastava JN, Satsangi GP, Kumar A (2008) Incidence of keratinophilic fungi in waterlogged condition of paddy soil. *J Environ Biol* 29(1):125–126
- Sigler L, Flis AL, Carmichael JW (1998) The genus *Uncinocarpus* (Onygenaceae) and its synonym *Brunneospora*: new concepts, combinations and connections to anamorphs in *Chrysosporium*, and further evidence of relationship with *Coccidioides immitis*. *Canad J Bot* 76:1624–1636
- Singh I, Kushwaha RKS, Parihar P (2009a) Keratinophilic fungi in soil of potted plants of indoor environments in Kanpur, India, and their proteolytic ability. *Mycoscience* 50:303–307
- Singh I, Kushwaha RKS (2010) Dermatophytes and related keratinophilic fungi in soil of parks and agricultural fields of Uttar Pradesh, India. *Indian J Dermatol* 55(3):306–308
- Singh I, Mishra A, Kushwaha RKS (2009b) Dermatophytes, related keratinophilic and opportunistic fungi in indoor dust of houses and hospitals. *Indian J Med Microbiol* 27(3):242–246
- Soni N, Prakash S (2011) Factors affecting the geometry of silver nanoparticles synthesis in *Chrysosporium tropicum* and *Fusarium oxysporum*. *Am J Nanotechnol* 2(1):112–121
- Soon SH (1991) Isolation of keratinophilic fungi from the soil in Malaysia. *Mycopathologia* 113(3):155–158
- Subrahmanyam A (1980) Mycotic infections of the scalp. *Hindustan Antibiot Bull* 22:62–100
- Sundaram BM (1987) Incidence of keratinophilic fungi in rice field soils. *Mycopathologia* 97(1):43–44
- Sur B, Ghosh GR (1980) Keratinophilic fungi from Orissa, India, II: isolations from feathers of wild birds and domestic fowls. *Sabouraudia* 18(4):275–280
- Thomas AD, Sigler L, Peucker S, Norton JH, Nielan A (2002) *Chrysosporium* anamorph of *Nannizziaopsis vriesii* associated with fatal cutaneous mycoses in the salt-water crocodile (*Crocodylus porosus*). *Med Mycol* 40:143–151
- Ulfig K (2000) The occurrence. In: Kushwaha RKS, Guarro J (eds) *Biology of dermatophytes and other keratinophilic fungi*, *Revista Iberoamericana de Micología*, Bilbao, pp 44–50
- Ulfig K, Guarro J, Cano J, Gene J, Vidal P, Figueras MJ, Lukasik W (1997) The occurrence of keratinolytic fungi in sediments of the river Tordera (Spain). *FEMS Microbiol Ecol* 22:111–117
- Ulfig K, Płaza G, Worsztynowicz A, Mańko T, Tien AJ, Brigmon RL (2003) Keratinolytic fungi as indicators of hydrocarbon contamination and bioremediation progress in a petroleum refinery. *Pol J Environ Stud* 12:245–250
- Ulfig K, Płaza G, Terakowski M, Janda-Ulfig K (2006) Sewage sludge open-air drying affects on keratinolytic, keratinophilic and actidione-resistant fungi. *Rocz Panstw Zakl Hig* 57(4):371–379
- Uri J, Valu G, Bekesi I (1963) Production of 6-a.p.a. by dermatophytes. *Nat Lond* 200:896–897
- Vanbreuseghem R (1952) Technique biologique pour l'isolement des dermatophytes duesol. *Ann Soc Belge Med Trop* 32:173–178

- Verma TN, Sinha BK, Das UL (1982) Isolation of keratinophilic fungi from the soil in Bihar (India). *Mykosen* 25:449–452
- Vidyasagar GM, Hosmani N, Shivkumar D (2005) Keratinophilic fungi isolated from hospital dust and soils of public places at Gulbarga, India. *Mycopathologia* 159(1):13–21
- Vissiennon T, Schuppel KF, Ullrich E, Kuijpers AF (1999) Case report. A disseminated infection due to *chrysosporium queenslandicum* in a garter snake (*Thamnophis*). *Mycoses* 42:107–110
- Yamagishi Y, Matsuoka M, Odagawa A, Kato S, Shindo K, Mochizuki J (1993) Rumbrin, a new cytoprotective substance produced by *Auxarthron umbrinum* I taxonomy, production, isolation and biological activities. *J Antibiot* 46:884–889
- Yamashita M, Tsurumi Y, Hosoda J, Komori T, Kohsaka M, Imanaka H (1984) Chryscandin, a novel peptidyl nucleoside antibiotic I taxonomy, fermentation, isolation and characterization. *J Antibiot* 37:1279–1283
- Zaki SM, Mikami Y, El-Din AA, Youssef YA (2005) Keratinophilic fungi recovered from the muddy soil in Cairo vicinities, Egypt. *Mycopathologia* 160(3):245–251
- Zelenková H (2006) *Geomyces pannorum* as a possible causative agent of dermatomycosis and onychomycosis in two patients. *Acta Dermatovenerol Croat* 14(1):21–25