WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
Coden USA: WJPRAP Impact Factor 8.63
Volume 15, Issue 17, 454-487. Review Article ISSN 2277–7105

PHYTOMEDICINAL APPROACHES TO FUNGAL SKIN DISEASES: A REVIEW OF PATHOGENS AND THERAPEUTIC PLANTS

Khushi Tiwari[1*], Rohit Yadav[2], Shikha Patidar[3]

[1]Institute of Pharmacy, Samrat Vikramaditya Vishwavidyalaya, Ujjain M.P.

[2]Assistant Professor, Institute of Pharmacy, Samrat Vikramaditya Vishwavidyalaya, Ujjain M.P.

[3]IPS Academy, College of Pharmacy, Indore M.P.

Article Received on 01 August 2026,
Article Revised on 21 August 2026,
Article Published on 01 Sept. 2026,

https://doi.org/10.5281/zenodo.22159304

***Corresponding Author**

Khushi Tiwari

Institute of Pharmacy, Samrat Vikramaditya Vishwavidyalaya, Ujjain M.P.

How to cite this Article: Khushi Tiwari[1*], Rohit Yadav[2], Shikha Patidar[3] (2026). Phytomedicinal Approaches To Fungal Skin Diseases: A Review Of Pathogens And Therapeutic Plants. World Journal of Pharmaceutical Research, 15(17), 454-487.

ABSTRACT

Skin plays a key role in protecting (the body) against pathogens and excessive water loss. Severely damaged skin will try to heal by forming scar tissue. Skin disease is a common ailment and it affects all ages from the neonate to the elderly. Antibiotics treatment for bacterial infections plays an important role in disease management because it is crucial to achieve better control and outcomes with infection. The action of these drugs can be broadly grouped into two main classes: bactericidal or bacteriostatic. many older antibiotics are no longer used because of significant side effects. New antibiotics are being developed, but the process is slow. Antimicrobial or anti-infective are other general terms. More specific terms include antibacterial medications, which treat infections caused by bacteria; antiviral medications, which treat infections like influenza, HIV, or hepatitis C; antifungal medications, which treat infections like yeast infections, toenail infections, or valley fever; and antiparasitic medications, which treat infections like malaria or tapeworms. An antifungal is a type of medication used to prevent or treat fungal infections by inhibiting the growth of fungi or killing them. These drugs target fungal structures such as the cell membrane, cell wall, or metabolic path ways, which are different from those in human cells. Early recognition and accurate diagnosis are essential for effective management and prevention of complications. Advances in dermatological therapies, including topical, systemic, and biologic treatments,

have improved patient outcomes considerably. Patient education, hygiene practices, and lifestyle modifications play a crucial role in long-term disease control.

KEYWORDS: Bactericidal, Antiparasitic, Pathogens, Subcutaneous, Depigmented, Vitiligo.

INTRODUCTION

Human skin, the outer covering of the body, is the largest organ in the body. It also constitutes the first line of defense. Skin contains many specialized cells and structures. It is divided into three main layers viz. epidermis, dermis and hypodermis. Each layer provides a distinct role in the overall function of the skin. Epidermis, the outer most layer of the skin, varies in thickness in different regions of the body. It is the thinnest on the eyelids (0.05 mm) and the thickest on the palms and soles (1.5 mm). The dermis also varies in thickness depending on the location of the skin. It is 0.3 mm on the eyelid and 3.0 mm on the back of the body. The dermis is attached to an underlying hypodermis or subcutaneous connective tissue. The subcutaneous tissue is a layer of fat and connective tissue that houses larger blood vessels and nerves. This layer is important in the regulation of temperature of the skin itself and the body. The size of this layer varies throughout the body and from person-to-person. Hair follicles, sweat glands and sebaceous glands are the main skin appendages.

The skin guards the underlying muscles, bones, ligaments and internal organs. There are two general types of skin, hairy and glabrous skin However, the skin can be dry, sensitive, pale, sagging or tired. People deficient in essential nutrients such as beta-carotene, the B complex vitamins and vitamins C and E often suffer from the drying of the skin.

FUNCTIONS OF SKIN

Because it interfaces with the environment, skin plays a key role in protecting (the body) against pathogens and excessive water loss. Its other functions are insulation, temperature regulation, sensation, storage and synthesis of vitamin D by action of ultraviolet (UV) and the protection of vitamin B folates, absorption of oxygen and drugs and water resistance. Severely damaged skin will try to heal by forming scar tissue. This is often discolored and depigmented.

COMMON SKIN PROBLEMS

Skin disease is a common ailment and it affects all ages from the neonate to the elderly and cause harm in number of ways. There are more than a thousand conditions that may affect the skin but most skin diseases can be categorized into nine common types.

Rashes

A rash is an area of red, inflamed skin or a group of individual spots. These can be caused by irritation, allergy, infection, an underlying disease, as well as by structural defects for example, blocked pores or malfunctioning oil glands. Examples of rashes include acne, dermatitis, eczema, hives, pityriasis rosea and psorasis.

Viral infections

These occur when a virus penetrates the stratum corneum and infects the inner layers of the skin. Examples of viral skin infections include herpes simplex, shingles (herpes zoster) and warts. Some systemic viral infections, such as chicken pox and measles, may also affect the skin. Viral infections cannot be cured with antibiotics.

Parasitic infections

These infections occur after exposure to parasites such as lice and scabies.

Pigmentation disorders

The amount of pigment in the skin is determined by the amount of melanin being produced by the body. Loss of pigment (hypo pigmentation) can be caused by absence of melanocytes, malfunctioning cells, exposure to cold or chemicals, or some types of infection. An increase in pigment (hyperpigmentation) may be caused by skin irritation, hormonal changes, aging, a metabolic disorder, or any other underlying problem. Age spots, freckles and melasma are examples of hyper pigmentation. Vitiligo is an example of hypo pigmentation.[1]

Bacterial infections

Such infections are caused by a variety of bacteria, the most common types being staphylococci and streptococci. Bacteria may infect the topmost layers of skin, the follicles, or the deeper layers of skin. If not treated correctly, these infections may spread throughout the body. Examples include impel folliculitis, cellulitis and lyme disease. Bacterial infections are better treated with antibiotics. It is important to have a good understanding of the common clinical manifestations and pathogens involved in bacterial skin infections to be able

to manage them appropriately. The type of skin infection depends on the depth and the skin compartment involved.

Impetigo

Impetigo is a superficial bacterial infection that can develop either through direct invasion of normal skin (primary) or infection at sites of damaged skin (secondary). It is common in children and is highly contagious.

There are two forms

• non-bullous or crusted impetigo – distinct yellow, crusting lesions that may be itchy. Typically involves face or extremities

• bullous impetigo – usually caused by Staphylococcus aureus. Presents as bullae that rupture to form a brown crust.

Folliculitis

This usually presents as a crop of pustules affecting areas of moist skin with hair. It is most commonly caused by S. aureus but can also be linked to other organisms like Pseudomonas aeruginosa when associated with specific exposures like hot tubs and spas.

Cellulitis and erysipelas

Both cellulitis and erysipelas manifest as spreading areas of skin erythema and warmth. Localised infections are often accompanied by lymphangitis and lymphadenopathy. Not infrequently, groin pain and tenderness due to inguinal lymphadenitis will precede the cellulitis. Some patients can be quite unwell with fevers and features of systemic toxicity. Bacteraemia, although uncommon (less than 5%), still occurs. Erysipelas involves the upper dermis and superficial lymphatics. Skin lesions are usually raised with a clear demarcation of infected skin. Classically, erysipelas affects the face, but it can also involve other areas such as the lower limb. It is most commonly caused by Streptococcus pyogenes (group A streptococcus). Cellulitis extends further into the deep dermis and subcutaneous tissue. It commonly involves the lower limbs and in most cases is unilateral. Bilateral lower limb cellulitis is exceedingly rare and usually reflects stasis dermatitis and does not require antibiotic treatment. Other areas of the body such as the eye and the abdominal wall can also be affected. Periorbital cellulitis involves the eyelids and does not extend into the bony orbit. Orbital cellulitis is a much more serious infection with deeper extension and impairment of vision and extraocular eye movements, often with pain.

Cellulitis is usually caused by either S. aureus or beta-haemolytic streptococci (groups A, B, C or G). Differentiating between these two organisms can help guide therapy. Streptococcal infection is usually characterised by acute onset of rapidly spreading erythema, lymphangitis and lymphadenopathy. Staphylococcal cellulitis is usually associated with purulent lesions with erythema. Cultures from wounds or blood can further help delineate the causative organism. In the absence of positive cultures however, it can be difficult to discriminate between the two and antibiotic therapy to cover both organisms (for example flucloxacillin, dicloxacillin, cephalexin, clindamycin) is often used.

Diagnostic approach to cellulitis

When evaluating a patient with cellulitis, review systemic features. Potential portals of entry for infection should also be looked for.

These include.

• disruption to the skin barrier, insect bites, wounds, abrasions
• pre-existing skin infection, tinea pedis, impetigo
• underlying skin disease, eczema, psoriasis
• lymphoedema or surgical disruption of the lymphatic or venous system
• peripheral vascular disease with impaired arterial supply
• chronic venous insufficiency.

Necrotising skin infections

Necrotising skin infections, the best known of which is necrotising fasciitis, are a medical and surgical emergency that require prompt debridement and appropriate intravenous antibiotics. Infections can be caused by single or multiple pathogens (e.g. S. pyogenes, Gram negatives, Clostridium). Infection usually involves the necrosis of underlying soft tissues or muscle. Typical early clinical features are induration and erythema of the affected area with pain out of proportion to overlying skin changes. As infection progresses, the skin can change colour to purple or blue and eventually breaks down to form bullae and gangrene. The patient is usually quite unwell with systemic toxicity, haemodynamic instability and multi-organ failure. Urgent hospital referral is essential in all cases. Surgical exploration is the only way to establish the diagnosis of necrotising fasciitis and is also the definitive management in all cases. Exploration also allows material to be obtained for appropriate cultures to guide antibiotic therapy.

Fungal infections

Harmless fungi are always present on surface of the skin. Infection occurs when these organisms enter into the body. These infections are usually superficial, affecting the skin, hair, nails and include athlete's foot, lock itch and ringworm. However, in people with suppressed immune system or who have been taking antibiotics for long period -, the fungi may spread to deep within the body, causing more serious disease.

Fungi

"Fungi are a kingdom of usually multicellular eukaryotic organism that are heterotrops and have important role in nutrient cycling in an ecosystem". Fungi are a diverse group of eukaryotic organisms that include microorganism such as yeasts, moulds and mushrooms. They obtain nutrients through absorption, breaking down organic matter in their surroundings. Structurally fungi consist of hyphae, which form a network called mycelium. They reproduce both sexually and asexually, and their life cycle often involves spore formulation. Fungi play crucial ecological roles as decomposers, symbionts and pathogens. Some are used in food production (yeast for baking), while others can cause diseases in plants and animals.

Characteristics of fungi

The fungi are eukaryotic, heterogeneous, unicellular to filamentous, spore bearing and chemo-organotropic organism which lack chlorophyll. Some fungi are single celled, while others are multicellular. Fungi cells have a nucleus and organelles, like plant and animal cells. The cell wall of fungi contain chitin, which is hard substance. They do not contain cellulose, which commonly makes up plant cell wall.

TYPES OF FUNGI

1. Chytridiomycota¬
2. Zygomycota¬
3. Glomeromycota¬
4. Ascomycota¬

1. Chytridiomycota

Chytridiomycota are usually asexual and produce spores that no around using flagella, small tail like appendages. It can cause fungal infection in frog by burrowing under their skin.

2. Zygomycota

These are mainly terrestrial. They cause problem by growing on human few source. Example: - Rhizopus stolonifera a bread mole.

3. Glomeromycota

They are found in soil. The fungi obtain sugar from plant and in return, dissolves, minerals in the soil to provide the plant with nutrients. These fungi reproduce asexually.[5]

4. Ascomycota

These are the pathogens of plant and animals, including human in which they are responsible for infection like athletes' foot, ringworm and ergotism, which causes vomiting, convulsions, hallucination and sometime even death.

Fungal infection is an inflammatory condition caused by a fungus. Fungal infection are common through much of natural world. In human, fungal infection occur when an invading

fungus takes over an area of the body and is too much for the immune system to handle. Fungi can live in the air, soil, water and plants. There are also some fungi that live in the human body.

Types of fungal infection

There are several types of fungal infection, including.

- Superficial Mycoses
- Cutaneous Mycoses
- Subcutaneous Mycoses
- Systemic Mycoses

Superficial Mycosis

It refers to fungal infections that primarily affect the outer layers of the skin, hair and nails. Unlike deep-seated fungal infections that involves internal organs, superficial mycoses are limited to the surface tissue.

Symptom

Itching

Redness and inflammation

Scaling or flaking of the skin

Circular or irregular rashes

Causes

Fungi, especially dermatophytes, candida and Malassezia are the primary causative agents. These fungi thrive in warm, moist environments.

Transmission

Direct contact with an infected person and animal.

Indirect transmission through contaminated object like towel, cloths etc.

Treatment

Topical antifungals: - Apply creams or powders with antifungal agent.

Oral medicament

Shampoos

Prevention

Hygiene: keep skin clean and dry.

Avoid moisture: Choose breathable fabrics, keep skin folds dry.

No sharing: avoid sharing personal items.

Regular check-up: Promote treatment and regular check-ups.

Cutaneous Mycoses

It is also known as dermatophytosis or ringworm infections, are fungal infections that affect the skin, hair and nails. They are caused by a group of fungi specialized in utilizing keratin, the protein found in skin, hairs and nails.

Symptoms

Itching

Redness

Scaling

Cracking

Blistering

Treatment

Topical antifungal: Creams, lotions or powders applied directly to the affected area.

Oral medication: In severe cases, oral antifungal medication may be prescribed.

Prevention

Hygiene maintains

Regular cleaning

Avoiding contaminated items.

Subcutaneous mycoses

These are fungal infections that involve the skin, subcutaneous tissue and occasionally deeper structures. These infections are caused by fungi that typically inhibit soil and plant material.

Symptoms

Painless nodules or papules at the site of entry.

Skin discoloration and swelling.

Causes

Fungi that commonly inhibit soil and plant materials.

Traumatic implantation of fungal elements into the skin through injuries, thorns or splinters.

Treatment

Antifungal medication, such as creams, lotions etc.

In severe cases, surgical intervention may be required to removed infected tissues.

Prevention

Protective measures: Use gloves and appropriate clothing when handling soil, plants or other materials that may herbal fungi.

Wound care: promptly clean and treat any wounds or injuries to prevent fungal entry.

Avoiding contaminated materials.

Systemic mycoses: There are fungal infections that affect internal organs and tissues.

Symptoms

Fever: Persistent or recurring fever is a common symptom.

Weight loss: unexplained weight loss may occur.

Fatigue: Generalized fatigue and weakness can be present.

Respiratory issues: Depending on the fungus, respiratory symptoms such as coughing and difficulty breathing may occur.

Joint pain: Some systemic mycoses may cause joint pain.

Night sweats: Excessive sweating, particularly during sleep.

Enlarge lymph node: swollen lymph nodes may be observed.

Treatment

Treatment typically involves antifungal medications and the choice depends on the type of fungus causing the infection.

It's crucial for individuals with systemic mycoses to be under the care of a health care professional, as these infections can be serious and require close monitoring during treatment.

Prevention

Avoidance: Minimize exposure to environments with high fungal infection.

Protective gear: Use appropriate protective gear (mask, gloves) when working in environments where exposure is likely.

Good hygiene: Practice good hygiene to reduce the risk of infection.

Immunization: In some cases, vaccines may be available for specific fungal infections.

Environmental control: Limiting exposure to known sources of fungi such as contaminated soil or bird droppings, can help prevent systemic mycoses.

Other skin fungal infection

Ringworm

Athlete's foot

Jock itch

Ringworm

Ringworm is a common fungal skin infection, that can affect the skin, scalp and nails. It's not caused by a worm but by various types of fungi known as dermatophytes.

Symptoms

Ringworm often presents as a red, itchy and circular rash on the skin, which may have a raised, scaly border. It can affect different part of body, including the scalp, body, feet and groin. Transmission: -ϖ It is highly contagious and can be spread through direct contact with an infected person, pet or contaminated surface like towels and shower floors.

Treatment

Antifungal medication such as topical creams or oral antifungal pills are commonly prescribed to treat ringworm. Over the counter antifungal creams may be effective for mild cases.

Prevention

Good hygiene.

Avoid sharing personal items.

Keep the skin clean and dry.

Athlete's foot

Athlete's foot also known as tinea pedis. It is common fungal infection affecting the skin of the feet, particularly between the toes. The fungi grow best in warm, moist placed. They are often found in the summer and in hot, humid climates.

Symptoms

It's symptoms including burning, itching and stinging sensation.

The skin may become red, scaly and cracked.

In severe cases, blisters and ulcers can develop.

Causes

It is caused by various types of fungi such as Trichophyton or Epidermophyton, that thrive in worm and moist place like sweat sock and shoes.

Transmission

The infection is contagious and can be spread through direct contact with infected skin or by touching contaminated surfaces such as shower floor, towels or socks.

Treatment

Over the counter antifungal cream, spray or powder are often effective for mild cases.

Prevention: - Good foot hygiene is essential

Keep feet clean and dry.

Wear breathable shoes and moisture wicking socks. Avoid walking barefoot in shared or damp environment.

Jock itch

Jock itch, also known as tinea cruris. It is a fungal infection that affects the skin in the groin area. It's caused by various fungi, typically those that thrive in warm and moist place. Infection happened most in the summer or warm, wet climate.

Symptoms

Redness: The affected area may appear red and irritated.

Itching: Persistent itching is common symptom.

Rash: A raised, red rash with defined edges may develop.

Flaking or peeling: The skin may flak or peel, especially at the edges of the rash.

Burning sensation: some individually may experience a burning or discomfort.

Causes

Fungal infection: Usually causes by dermatophytes.

Warm and moist condition: Fungi thrive in warm, humid environments, making the groin area susceptible.

Treatment

Antifungal creams: Over the counter cream containing ingredient like miconazole are commonly used.

Keeping the area dry: Good hygiene and ensure the affected area stay dry and can aid recovery.

Prescription medications: IN severe cases, a health care professional may prescribe stronger antifungal medication.

Prevention

Good hygiene: Regularly clean and dry the groin area, especially after sweating.

Loos clothing: Ware loos fitting, breathable clothing to minimize moisture.

Avoid sharing personal items: towels, clothing or other personal items should not be shared to prevent spreading the infection.[3]

Acne

Acne vulgaris or simply known as acne is a human skin disease characterised by skin with scaly redskin (seborrheas), blackheads and whiteheads (comedones), pinheads (papule), large papule (nodules), pimples and scarring. Acne affects skin having dense sebaceous follicles in areas including face, chest and back. Acne may be of inflammatory or non-inflammatory forms. Acne is usually caused by increase in androgens level like testosterone mainly during puberty in both male and female.[4]

Treatment Of Bacterial and Fungal Infections

Bacterial Infections

Bacterial infections continue to be a major public health challenge due to the large number of potential pathogens and varying disease states from mild or asymptomatic to life-threatening conditions (WHO, 2023). After all, one of the increasingly worrisome opportunistic pathogens is Acinetobacter baumannii, because it is a multi-drug-resistant strain, which compromises the arsenal of treatment options that healthcare providers have to manage diseases. Antibiotics treatment for bacterial infections plays an important role in disease management because it is crucial to achieve better control and outcomes with infection (Uddin et al., 2021). Misuse and overuse of antibiotics have led to the development of

increased resistance in microbes; therefore, appropriate policies need to be implemented. Several studies have admitted that such a program was effective in stemming resistance and promoting the rational use of antibiotics (Funes, 2019). Furthermore, innovative approaches, including the use of bacteriophages, are being explored alongside traditional antibiotics to enhance treatment efficacy against resistant strains (Styles et al., 2020). Thus, understanding the dynamics of bacterial infections and the strategic use of antibiotics is crucial in combating resistance and ensuring effective treatment.

Mechanism of Action of Antibiotics

Antibiotics specifically interfere with a very particular process that is necessary for bacterial life and replication; most of the time, they inhibit growth or wipe them out entirely. The action of these drugs can be broadly grouped into two main classes: bactericidal or bacteriostatic. Bactericidal antibiotics like penicillin interrupt synthesis related to the bacterial cell wall and then, by osmotic forces, the cell lyses (Lillestolen et al., 2018). Bacteriostatic antibiotics inhibit proteins that are used by bacteria to replicate themselves, therefore stopping their proliferation while not necessarily killing them. This action is very important for the therapeutic activities of the bacteriostatic agents included in them since bacterial pathogenicity depends on proteins' normal function; then, the immune system of the body can eradicate an infection much more efficiently. Consequently, understanding these mechanisms is essential for developing effective treatments and combating antibiotic resistance (Mongold, 2020).

Antibiotic Resistance

Pathogenic microbes can develop ways to evade antibiotics, increasing the risk of infections that are difficult to treat. Antibiotic resistance is increasing and is a top global public health threat. One response to this threat is reintroduction of older antibiotics that previously had fallen out of use. However, many older antibiotics are no longer used because of significant side effects. New antibiotics are being developed, but the process is slow. Government agencies and professional organizations are involved in efforts to promote development of new antibiotics, and several new antibiotics have been approved in the last few years. Another response is that a different way to treat bacterial infection, called phage therapy, is under research. Bacteriophages are viruses that infect and kill specific bacteria and can be used to treat bacterial infection because bacteriophages do not infect humans. Phage therapy was first recognized in the beginning of the 20th century but was overshadowed by discovery

of antibiotics. In addition to treating antibiotic-resistant bacteria, phage therapy targets specific bacteria, whereas antibiotics affect a large range of bacteria, even the normal, beneficial ones in the digestive tract. Phage therapy is still experimental and is not yet approved by the US Food and Drug Administration. Viruses, fungi, and parasites can develop resistance to antibiotics too. HIV develops resistance easily, so patients with HIV always take more than 1 type of antiviral medication to reduce development of resistance. Candida auris is a new pathogenic fungus that can be resistant to all antifungal medications. Malaria is an example of a parasite that has developed resistance to many antiparasitic medications, limiting public health efforts to control it globally.

Types of Antibiotics

The term antibiotic usually refers to medications that treat bacterial infections like strep throat, ear infection, or urinary tract infection. But it can be a more general term for medications that kill any type of microbe. Antimicrobial or anti-infective are other general terms. More specific terms include antibacterial medications, which treat infections caused by bacteria; antiviral medications, which treat infections like influenza, HIV, or hepatitis C; antifungal medications, which treat infections like yeast infections, toenail infections, or valley fever; and antiparasitic medications, which treat infections like malaria or tapeworms.[6]

ANTI FUNGAL

An antifungal is a type of medication used to prevent or treat fungal infections by inhibiting the growth of fungi or killing them. These drugs target fungal structures such as the cell membrane, cell wall, or metabolic path ways, which are different from those in human cells.

TYPES OF ANTI FUNGAL MEDICATIONS

Pharmacology and Toxicity of Antifungal Agents Due to its limited water solubility, amphotericin B is linked to sodium deoxycholate in the medication formulation. Following intravenous injection, AMB binds to plasma lipoproteins, separates from deoxycholate, and builds up in the liver and spleen. AMB has an elimination half-life of more than 15 days. It is not broken down by CYP450 enzymes and is instead eliminated as an unaltered medication in the urine (33%) and feces (43%). The toxicity of AMB deoxycholate, both infusion- and dose-related, is one of its fundamental drawbacks. The activation of proinflammatory cytokines and chemokines, including interleukin 1β, tumor necrosis factor α, monocyte chemotactic protein 1, and macrophage inflammatory protein, is the cause of the

infusionrelated toxicity.5-flucytosine, on the other hand, is a tiny hydrophilic molecule that absorbs quickly and has a nearly 90% bioavailability. 5-FC is barely metabolized by liver enzymes. Its plasma clearance is as quick as creatinine clearance, and it is completely removed via glomerular filtration, which has strong antifungal activity in the bladder. Because 5-FC has a half-life of up to four hours, it is dosed often. Because susceptible cells use the same transport mechanism, 5-FC's antifungal action is competitively inhibited when administered with cytarabine, a medication that effectively treats acute myeloid leukemia. Hepatotoxicity, myelotoxicity, and gastrointestinal issues are examples of severe adverse effects.[7]

Existing anti-fungal drugs

Polyenes

Polyenes are the oldest family of antifungal drugs which were introduced as early as in 1950s. Many polyenes have been isolated from Streptomyces spp., but only Amphotericin B (AmpB) remains in widespread use, especially with the advent of its many formulations like liposomal AmpB, topical nystatin, and AmpB lipid complex. It has been known that polyenes, including Amp B which is a bigger polyene, interact with the membrane sterols, mostly ergosterol, which leads to the formation of aqueous pores. In the case of AmpB, the pore contains an annulus of 8 molecules of AmpB which is hydrophobically attached to the membrane sterols. This structure causes the formation of a pore in which the polyene hydroxyl is placed inward and leads to leakage of essential components of cytoplasm, modified permeation of substances, and thus leads to the death of the fungal cell. Polyenes have shown a wide range of activity. They have exhibited efficiency against Candida spp., Fusarium spp., Aspergillus spp., as well as Mucorales. But at the same time, polyenes have been able to show only limited activity against Scedosporium spp.

Echinocandins

Echinocandins are comparatively the newest antifungal class and majorly include caspofungin, anidulafungin, and micafungin. The fungal cell membrane consists of a heteromeric glycosyltransferase enzyme complex known as Beta-(1,3)-D-glucan synthase, which is primarily made of catalytic Fks p subunit and a regulatory subunit belonging to the family of Rho GTPase.[33] The regulatory and catalytic subunits are linked to the UDP-glucose and GTP, intracellularly. Echinocandins exhibit their fungicidal activity against the pathogens through non-competitive binding to the Fks p subunit of the enzyme and blocking

the beta-(1,3)-D-glucan synthesis, which ultimately leads to a highly permeable and leaky cell wall and causes an imbalance in the osmotic pressure intracellularly, thus, resulting in cell lysis of the fungal cell. Echinocandins show their fungicidal action against Candida ssp. and Aspergillus ssp. But they are not active against Scedosporium spp., Fusarium spp., and Cryptococcus spp. and are thus not recommended for the treatment of infections caused by these species.

Heterocyclic benzofuran Griseofulvin

Heterocyclic Benzofuran is an inhibitor of microtubule assembly. It combines with microtubules to modify the synthesis of the mitotic spindle, which leads to the inhibition of mitosis in the fungal cells. By demonstrating this action, Griseofulvin acts as a fungistatic substance against various species of fungi like Epidermophyton, Microsporum, and Trichophyton. But, it is not effective for the treatment of chromomycosis, dimorphic fungi, and yeast (Malassezia, Candida). Griseofulvin has a less half-life and is easily eliminated from the body; therefore, it should be administered over an extended period of time for better effectiveness.

Antimetabolites

5-Fluorocytosine (5FC) is the only available antimetabolite. It is a fluorinated pyrimidine that exhibits anti-fungal actions against various fungal species like yeasts (Candida and Cryptococcus neoformans). The permease enzyme enables the 5FC to permeate into the fungi. As a result, the enzyme cytosine deaminase converts 5FC into 5-fluorouracil (5FU), which is then converted into 5-fluorouridylic acid (FUMP) by UMP pyrophosphorylase, and then FUMP is further phosphorylated and then inserted into the fungal RNA, thus, causing interference for the synthesis of proteins. 5FU is also transformed into 5-fluorodeoxyuridine monophosphate, which causes inhibition of thymidylate synthase that plays a major role in nuclear division and synthesis of DNA. Therefore, 5-fluorocytosine not only inhibits the metabolism of pyrimidine but also interferes with the synthesis of DNA, RNA, and proteins in the fungal pathogen. 5-Fluorocytosine has exhibited secondary resistance which has prompted combining fluconazole or AmpB for administering the same to patients.

Azoles

The activity of azoles is similar to that of polyenes as they also target the fungal cell membrane. Ergosterol, which is an essential component of the fungal cell membrane, maintains its fluidity and asymmetry and thus provides integrity in the cells of fungi. The lack

of C-4 methyl groups in the sterols is essential for maintaining the integrity of the fungal cell membranes. Azoles mainly target the heme protein which cocatalyzes cytochrome P-450-dependent 14a-demethylation of lanosterol. The degradation of the 14a-demethylase leads to the destruction of ergosterol and accumulation of the precursors of the sterol which also includes 14a-methylated sterols (24-methylenedihydrolanosterol and lanosterol, 4,14 dimethyl zymosterol), therefore, causing modifications in the structure and functions of the cell membrane. Azoles have exhibited fungicidal activity against Aspergillus spp., whereas they show fungistatic activity against Candida spp. Azoles have been effective against Cryptococcus spp.; however, they have shown mixed and limited activity against Mucorales, Scedosporium spp., and Fusarium spp.

Allylamines

Allylamines are a comparatively newer class of antifungals that include naftifine and terbinafine. Terbinafine is both orally and topically effective against dermatophytes (Epidermophyton spp., Microsporum, Trichophyton) and Candida. Allylamines exhibit antifungal activities by interfering with the biosynthesis of ergosterol, which also leads to the accumulation of the sterol precursor-like squalene and the absence of other intermediates of sterol; therefore, allylamines cause inhibition of synthesis of sterol during squalene epoxidation (a reaction step that catalyzes the squalene epoxidase). The death of the fungal cells is mainly associated with the accumulation of squalene than the deficiency of ergosterol. The increased amount of squalene in the fungal cells can lead to more permeation across the cell membranes, therefore causing interference with the cellular organization. Terbinafine, when applied topically, causes adverse events like gastrointestinal disturbance, erythema, urticaria, rashes, neutropenia, and musculoskeletal reactions. Similarly, Naftifine has known to cause mild rash, erythema, and moderate burning when applied topically in the application area.[8]

Resistances

The antimicrobial spectrum of activity refers to the range of fungal species an antimicrobial agent can effectively inhibit. To evaluate the sensitivity of a pathogen to an antifungal agent, in vitro susceptibility studies are performed. The latter enable the quantification of either minimal inhibitory concentration (MIC) or minimal effective concentration (MEC) values. For example, MIC50 and MIC90 are usually used as the minimum concentrations of an antifungal agent that inhibit the growth of 50% and 90% of the isolates of the tested fungal

population, respectively, relative to a growth control. It is usually given in a microgram per milliliter (μg.mL−1) unit, whereas a result in micromole per milliliter (μmol.mL−1) would be preferable to reliably compare compounds whose structures (and molecular weights, consequently) are frankly different. On the other hand, the MEC is defined as the minimum concentration of an antifungal that causes the growth of aberrant short hyphal segments. The European Committee for Antimicrobial Susceptibility Testing (EUCAST) guidelines and Clinical and Laboratory Standards Institute (CLSI) have developed broth microdilution protocols that are used today as standardized methods to assess these values. Both EUCAST and CLSI protocols include the use of defined concentrations of antifungal agents in liquid culture media. To determine the MIC of an antifungal substance, both organizations have similar criteria. For flucytosine, azoles, and echinocandins, the 50% inhibition is determined in both protocols. For amphotericin B, complete growth inhibition is required by CLSI, whereas only a 90% growth decrease is required by EUCAST. However, important differences between these two methods may significantly impact the MIC determination. Notably, the preparation of the putative antifungal substances, the inoculum size, and the glucose content in the culture media are different. Also, in the CLSI method, the MIC determination relies on visual reading using a viewing mirror, whereas the EUCAST method employs a spectrophotometer microplate reader, providing more reliable and repeatable results. Alternative methods for assessing MIC values, such as disk diffusion, present a high inter-laboratory variability. This explains the variability in MIC and MEC values reported in the literature. As versatile and potent microorganisms, fungi can develop mechanisms to withstand unfavorable environmental conditions. This adaptation capability is a key reason why fungal species that are normally susceptible to an antifungal agent can acquire resistance to it. Moreover, fungi can be multinucleated and/or multicellular and can carry multiple chromosomes, providing enhanced opportunities for genetic modifications and emergence of resistances due to selection pressures from repeated exposure to an antifungal agent (Table 1). Phenotypic heterogeneity can also impact antifungal susceptibility. Like bacteria, fungi can form organized and complex communities called biofilms that consist of fungal cells surrounded by an extracellular matrix mainly composed of polysaccharides. This acts as a barrier that sequesters antifungal drugs, preventing their access to the fungal cells. Therefore, biofilm formation is a non-genetic strategy developed by fungi to resist to antifungal drugs and to survive.

Resistances to Polyenes Polyenes are a class of antifungals with fungicidal properties in most fungi. Resistance to this antifungal family is uncommon, but it can be intrinsic for fungi such as C. haemulonii, C. auris, C. lusitaniae, Trichosporon spp., A. terreus and A. flavus, Scedosporium spp., Lomentospora spp., and Fusarium spp. The fact that resistance to polyenes is a rare occurrence might be the consequence of the severe fitness trade-off related to its acquisition and to the fact that polyenes target a major wall component, not just an enzyme, which other antifungal family's target. Amphotericin B exerts its functions at the fungal plasma membrane and extracellularly, which determines mechanisms of resistance different from the antifungals with an intracellular activity. Ergosterol is the target of polyenes, and the proportion of ergosterol and alterations in the membrane sterol composition can affect susceptibility to them. A reduction in ergosterol content can be a consequence of mutations in genes like Erg1, Erg2, Erg3, Erg4, Erg5, Erg6, Erg11, and Erg13, which can lead to a lower level of the therapeutic target. Polyenes also promote ROS formation and their accumulation in fungal cells, which leads to oxidative stress. Yet, the degree of this accretion can vary from species to species and from isolate to isolate. Candida haemulonii, a yeast species showing a high proportion of amphotericin-B-resistant isolates, is able to tolerate a higher concentration of ROS compared to other Candida species. Heat-shock proteins 90 (HSP90) and 70 (HSP70) are key players in controlling cellular stress, and genes encoding for these proteins have been associated with amphotericin B resistance in A. terreus, C. auris, and Trichosporon spp. HSP90 stabilizes signal transductors implicated in antifungal-induced stress in Candida, Cryptococcus, and Aspergillus species, but their roles in the acquisition and maintaining of polyene resistance need further investigation. Another mechanism of resistance to amphotericin B described in C. haemulonii is the shift from aerobic respiration to fermentation. This phenomenon is induced by amphotericin B and leads to a decrease in intracellular ROS. In addition to altered metabolic status, iron homeostasis and post-translational modification are other mechanisms implicated in amphotericin B resistance.

Resistances to 5-FC

Flucytosine disrupts nucleic acid biosynthesis within the cell, and it requires activation within the fungal cell via metabolism by the pyrimidine salvage pathway. It is active against Cryptococcus spp., most Candida spp., and some agents of chromoblastomycosis, and it has limited effect on molds. Flucytosine resistance is rapid and extremely frequent, which discards monotherapy. This can be attributed to a defect in intracellular penetration or to a shortcoming of the metabolism of the prodrug into 5-FU, which is the active cytotoxic agent.

In pathogenic Candida spp., loss or mutations in Fca1/Fcy1, Fcy2, Fur1, and Msh2 genes have been implicated in resistance to 5-FC. Its place in antifungal treatment is mostly against cryptococcal meningitis as part of combinations with amphotericin B—shown to accelerate the rate of clearance of the infective agent and reduce mortality, and with fluconazole—demonstrated to prevent the selection of resistant strains. Flucytosine associated with amphotericin B is also used in treating Candida endocarditis, endophtalmitis, and hepatosplenic or osteoarticular infections.

Resistances to Azoles

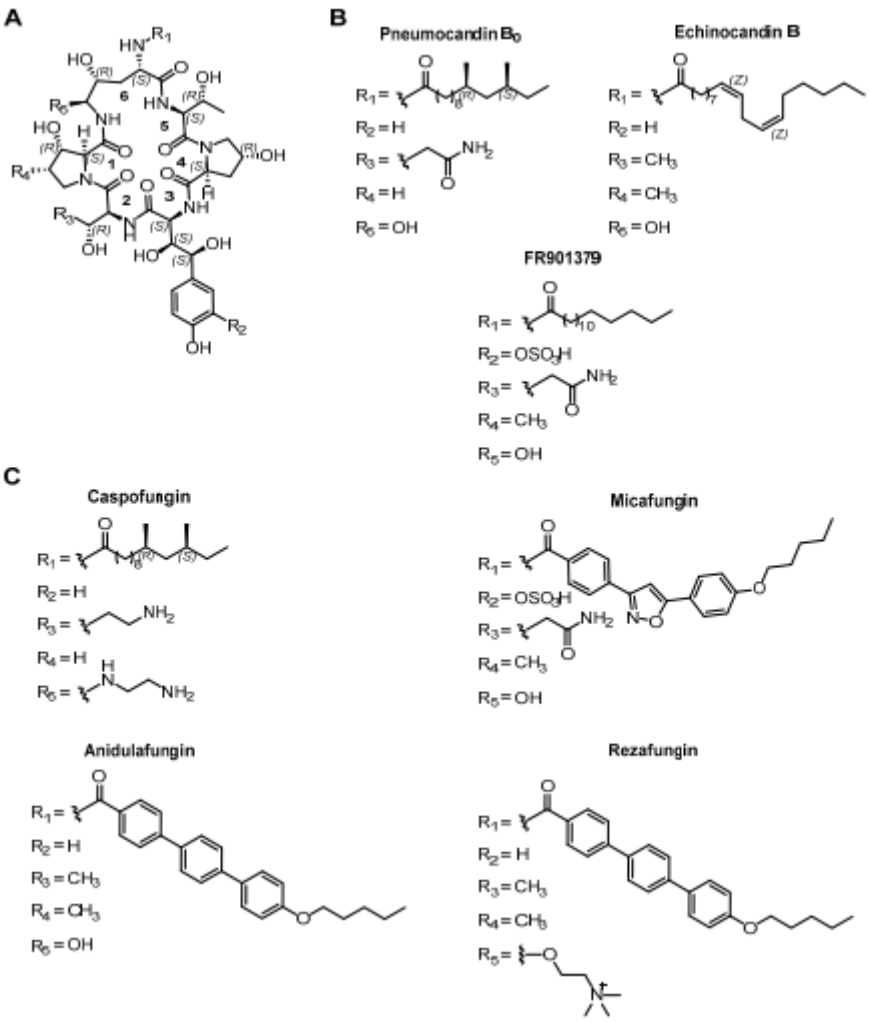
Azoles target the fungal cell membrane and block ergosterol biosynthesis, leading to intracellular build-up of a toxic sterol. They have a fungistatic effect on yeasts and fungicidal activity on Aspergillus spp. Pichia kudriavzevii/Candida krusei is innately resistant to fluconazole, and 87–100% of C. auris are reported as resistant to these antifungals. C. glabrata's, now called Nakaseomyces glabratus, azole resistance varies from 9–10% in the SENTRY Antifungal Surveillance Program to 86% in Slovenia and 100% in Croatia, as reported by a multinational study looking into candidemia trends. The same authors found 73% of C. parapsilosis strains to be resistant to azoles in Italy and 81% in Croatia. Fluconazole is not active on molds, and Aspergillus can become resistant to the other triazoles, with reported data varying from 0.3% in Austria to 13% in the UK and 25% in the Netherlands. Heteroresistance is defined as the presence of intrinsic resistance to a drug in a minority subpopulation that could be selected by treatment and become dominant. This has been described for fluconazole with C. neoformans and C. glabrata. Many mechanisms can be responsible for azole resistance and can even be combined in a single isolated resistant strain. Among the main mechanisms one can find (i) the modification of 14α-demethylase by mutation of the corresponding encoding gene; (ii) the overproduction of the target; (iii) the overexpression of efflux pumps leading to a collapsed bioavailability of the azoles and (iv) compensating modifications of other steps of ergosterol biosynthesis leading to the overcoming of the target enzyme inhibition. Drug target alteration or overexpression of the Erg11 gene in yeasts and Cyp51 in molds is a well-explored and common mechanism leading to acquired azole resistance. In the case of C. albicans, 140 different Erg11 amino acid substitutions have been described, the majority within three hot-spot regions. In A. fumigatus, the Cyp51 isoenzymes are encoded by genes Cyp51 A and Cyp51 B, and while the former has been well-studied and characterized, the role of the latter is less understood. Intrinsic azole resistance in A. lentulus has also been linked to the CypA gene. Specific amino acid

substitutions like TR34/L98H and TR46/Y121F/T289A coupled with duplications in the Cyp51A promoter gene are associated with azole resistance in environmental and clinical isolates. Mutations in the Erg3 gene have been shown to determine azole resistance in C. albicans and C. parapsilosis. Resistance to azoles also involves upregulation of plasma membrane efflux pumps responsible for reduced accumulation of these intracellular drugs. Higher efflux pump activity has been reported in the C. haemulonii species complex, which has low susceptibility to azoles and echinocandins. Candida biofilms have intrinsic antifungal resistance, and in some cases, the fluconazole concentration required for inhibition is a thousand times higher when compared to planktonic cells.

Resistances to Echinocandines

Echinocandins target the fungal cell wall via inhibition of (1,3)-β-D-glucan synthase. Mucorales and basidiomycetes such as C. neoformans are intrinsically resistant, but the members of this antifungal family are fungicidal on Candida and fungistatic on Aspergillus. 65 Out of the less susceptible yeast species, 2–13% of C. glabrata and 0–8% of C. auris have been reported as resistant to echinocandins. C. parapsilosis, Meyerozyma/Candida guilliermondii, and C. haemulonii species complex also have low susceptibility to this drug class. Attenuated antifungal activity at high drug concentrations is known as the paradoxical growth effect or “Eagle effect” and characterizes caspofungin and molds, mostly Aspergillus. It is well-established that mutations in the Fks genes (Fks1, Fks2, and Fks3), coding for the catalytic sub-unit of 1,3-β-D-glucan synthase, results in reduced susceptibility to echinocandins. In fact, mutations such as point mutations, gene duplications, and transposon insertions are common in fungi. Thus, mutations of Fks genes are found in highly conserved regions called hot-spots. The majority of mutations described in Candida, Aspergillus, and Cryptococcus isolates presenting an acquired resistance to echinocandin hot-spots are present in the Fks1 gene, which is an essential gene in C. albicans. In contrast, in C. glabrata, Fks1 and Fks2 are functionally redundant for viability, and mutations can also occur in the Fks2 gene. In Aspergillus, Fks1 mutations in vivo are associated with a high fitness cost and resistance in rare cases. The acquisition of resistance to echinocandins is strongly dependent of the position of and specific amino acid mutations, which can be substitutions, deletions, or insertions. These mutations reduce the catalytic efficiency of 1,3-β-D-glucan biosynthesis, inducing modifications in the cell wall composition. Moreover, Fks gene mutations can cause cross-resistance to all echinocandins. In C. glabrata and C. parapsilosis, mutations in the Erg3 gene can also be acquired upon echinocandin exposure in vitro and result in resistant strains

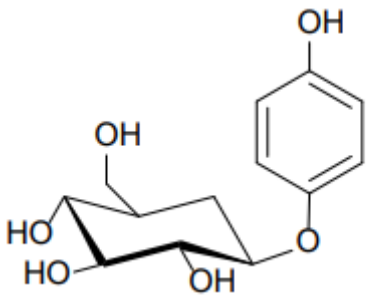
and determine cross-resistance to fluconazole. Fungi also present compensatory adaptive mechanisms that can induce cell wall repair in response to disruption by echinocandins. The cell stress induced by the inhibition of β-glucan synthase indirectly activates the Protein Kinase C–Mitogen-Activated Protein Kinase (PKC-MAPK) pathway, which is responsible for intermittent reconstruction of the cell wall, through the upregulation of chitin and mannan. The compensatory chitin synthesis can also be activated by the Ca2+/calcineurin and high-osmolarity glycerol (HOG) pathways, which are involved in drug tolerance. Remarkably, Fks2 expression in C. glabrata is calcineurin-dependent, suggesting that it could be regulated synergistically with calcineurin inhibitors. The upregulation of chitin has also been shown to be calcineurin-related in C. albicans and A. fumigatus. There is a growing interest in the implication of epigenetic modifications in antifungal acquired resistance, but their impact needs to be explored further.[9]



Medicinal Plants Used in Treatment of Infections

Bergenia crassifolia

Bergenia crassifolia, a perennial herbaceous plant belonging to the family Saxifragaceae, is native to Siberia, the Altai Mountains, Mongolia, China, and Korea. It typically grows on rocky slopes, screes, and within coniferous and deciduous forests, preferring shaded and moist habitats. Phytochemical investigations of species within the Bergenia genus, including B. crassifolia and B. cordifolia, have revealed a high content of arbutin, flavonoids, hydroxycinnamic acids, polyphenols, and tannins—compounds known for their dermatological activity. Arbutin (Figure 1), the principal bioactive constituent of these plants, exerts a pronounced depigmenting effect by inhibiting tyrosinase, a key enzyme involved in melanin biosynthesis. High-performance liquid chromatography with ultraviolet detection (HPLC-UV) analysis showed that the arbutin content in the leaves of various Bergenia specimens ranged from 4.8 to 9.8 g/100 g, with the highest levels reported in samples collected from Finland.



Structural formula of arbutin—the main bioactive phenolic glycoside of Bergenia crassifolia.

In addition, substantial concentrations of polyphenolic compounds (up to 9.27 g/100 g), tannins (up to 6.7 g/100 g), and hydroxycinnamic acids (up to 2.42 g/100 g) underscore the potential therapeutic relevance of Bergenia species in the treatment of inflammatory and hyperpigmented skin conditions. The co-presence of arbutin and other phenolic constituents suggests a possible synergistic interaction, potentially enhancing the overall dermatological efficacy of Bergenia-based formulations.

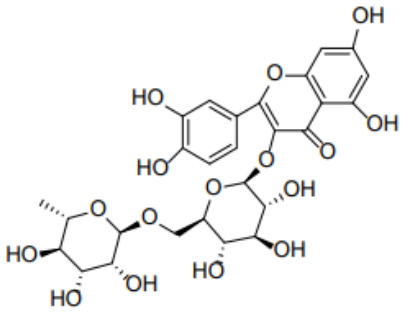
Phytotherapeutic application and chemical composition of Bergenia crassifolia.

A study published in the Mongolian Journal of Chemistry investigated the woundhealing activity of a composition based on a hydrogel of poly(hexamethylene guanidine) hydrochloride combined with an extract of Bergenia crassifolia in a thermal burn model on laboratory animals. The results demonstrated that this formulation contributes to the normalization of antioxidant activity and leukocyte levels. Morphological analysis revealed that wound healing was significantly accelerated in the treatment group compared to the control, as evidenced by a reduction in the thickness of the leukocyte-necrotic eschar, enhanced epithelialization, and complete closure of the skin defect. Bergenia crassifolia is also utilized in cosmetic products aimed at pore tightening, reducing oily skin shine, and overall improvement of skin condition. Decoctions and infusions prepared from its leaves and rhizomes are commonly applied in the form of lotions, facial rinses, and compresses. In clinical settings, Bergenia-based formulations are used in the treatment of burns and trophic ulcers as part of combination therapy, promoting epithelial regeneration and protecting damaged tissue from microbial infection.

Black Elderberry (*Sambucus nigra*)

Sambucus nigra is a perennial shrub belonging to the family Adoxaceae, widely distributed in the temperate regions of Europe, North Africa, and Western Asia. Its flowers and fruits have been traditionally and officially employed in medicine, including in dermatology and cosmetology applications. The flowers of S. nigra contain flavonoids (notably rutin (Figure 3) and quercetin), essential oils, organic acids (such as malic, acetic, and valeric acids), tannins, and mucilaginous compounds. The fruits are rich in anthocyanins, vitamin C, B-complex vitamins, sugars, pectins, and carotenoids. Due to this diverse phytochemical profile,

Sambucus-based preparations exhibit antioxidant, anti-inflammatory, bactericidal, and anti-edematous properties. In a study by, the anti-inflammatory properties of Sambucus nigra leaf extracts were investigated. The results demonstrated that the extracts suppressed the secretion of tumor necrosis factor-alpha (TNF-α) and reduced the production of reactive oxygen species (ROS) in lipopolysaccharide (LPS)-stimulated neutrophils. These findings highlight the anti-inflammatory potential of S. nigra leaves, indicating their relevance as a botanical source for treating inflammatory skin conditions.



Structural formula of rutin—a key flavonoid component found in Sambucus nigra flowers and Solidago Canadensis.

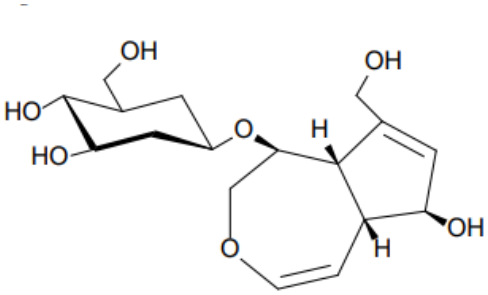
Berry extracts of Sambucus nigra obtained by supercritical fluid extraction exhibited promising potential for the prevention and treatment of dermatological disorders, primarily through the inhibition of collagenase and elastase—key enzymes involved in the degradation of the extracellular skin matrix. The most potent inhibitory activity was observed in the extract derived from dried berries using absolute ethanol, with collagenase inhibition reaching 84.7%, comparable to the positive control (white tea extract). Additionally, the same extract demonstrated high elastase inhibitory activity (77.3%), exceeding that of the reference compound ursolic acid. As these enzymes are critically involved in skin aging, inflammation, and loss of elasticity, the findings underscore the dermatological significance of Sambucus nigra extracts. Moreover, these extracts exhibited antioxidant properties and were successfully encapsulated in PLGA-based polymeric nanoparticles, which improved their stability and potential skin permeability. The resulting nanostructures maintained their bioactivity and exhibited a skin-compatible pH profile, supporting their potential application in dermatological and cosmetic formulations. Fruit extracts of Sambucus nigra also demonstrated strong anti-photoaging and antiinflammatory effects in a UVB-induced human keratinocyte (HaCaT) damage model. Treatment with the extract significantly reduced ROS

production, and inhibited the expression of matrix metalloproteinase-1 (MMP-1), interleukin-6 (IL-6), and vascular endothelial growth factor (VEGF), suggesting a protective effect against collagen degradation and inflammation. The underlying mechanisms included inhibition of the MAPK/AP-1 and NF-κB pathways, as well as activation of the Nrf2/HO-1 antioxidant system and the TGF-β/Smad signaling cascade responsible for type I procollagen synthesis. These results suggest that Sambucus nigra is a promising botanical agent for the prevention and treatment of photoaging and UV-induced inflammatory skin conditions.

Broadleaf Plantain (*Plantago major*)

Plantago major L., a member of the Plantaginaceae family, is a perennial herbaceous plant widely distributed across temperate and subtropical regions of Europe, Asia, and the Americas. It commonly inhabits anthropogenic environments such as roadsides, wastelands, pastures, and disturbed landscapes, reflecting its high adaptability to adverse ecological conditions.

The phytochemical composition of Plantago major is characterized by a wide range of biologically active compounds, including phenolic acids (notably chlorogenic and ferulic acids), iridoid glycosides (aucubin and catalpol), flavonoids (apigenin and luteolin), polysaccharides, tannins, and saponins. Recent studies have confirmed the plant's antioxidant, anti-inflammatory, antibacterial, and wound-healing activities, which are attributed to these constituents. Of particular interest is aucubin (Figure 4), a compound with pronounced biological activity that inhibits pro-inflammatory cytokines and promotes tissue regeneration.



Structural formula of aucubin, the main bioactive iridoid glycoside found in Plantago major.

In traditional medicine across Europe and Central Asia, the leaves of Plantago major are used to treat wounds, burns, ulcers, skin irritations, as well as respiratory and digestive disorders. In Traditional Chinese Medicine (TCM), the plant is recognized for its ability to clear internal

heat, promote wound healing, and reduce inflammation. Ethnobotanical studies conducted in Russia and Kazakhstan have documented the widespread use of Plantago major in the form of decoctions, infusions, and topical ointments for the treatment of various skin conditions and wounds, supporting its potential as a promising ingredient in dermatological preparations.

Canadian Goldenrod (*Solidago canadensis*)

Solidago canadensis is a perennial herbaceous plant belonging to the Asteraceae family, widely distributed across North America and introduced to Europe and Asia. In both traditional and official medicine, the aerial parts of the plant are used, being rich in biologically active constituents. Solidago canadensis is characterized by a diverse phytochemical composition, including flavonoids, saponins, terpenoids, phenolic acids, essential oils, and alkaloids. The presence of these constituents underlies its investigated pharmacological activities— anti-inflammatory, antimicrobial, and diuretic effects. In European traditional medicine, it has been used for over 700 years, particularly in the treatment of urinary tract disorders, skin inflammations, rheumatism, gout, and eczema. Contemporary studies confirm that S. canadensis extracts exhibit antibacterial, antiseptic, analgesic, diuretic, anti-inflammatory, and antioxidant effects (Figure 5). In particular, the plant's essential oils have demonstrated activity against pathogenic fungi (Botrytis cinerea), Gram-positive bacteria, and Salmonella, as well as potent insect-repellent properties. Flavonoids and phenolic compounds isolated from the plant show strong free radical scavenging capacity, positioning Solidago canadensis as a promising candidate for the development of phytotherapeutic and cosmetic products aimed at skin restoration, inflammation control, and prevention of age-related skin changes.

The leaves of Solidago canadensis are rich in a complex array of phenolic compounds, among which rutin (quercetin-3-O-rutinoside) (Figure 3) is the predominant flavonoid, known for its potent antioxidant and anti-inflammatory properties. Studies have shown that rutin and other flavonoid glycosides are capable of forming complexes with ammonium ions, resulting in novel polar compounds with notable biological activity.

Phytotherapeutic application and chemical composition of Solidago canadensis.

These complexes exhibit stimulatory effects on root growth in soybean and chrysanthemum seedlings, particularly promoting lateral root formation, suggesting potential applications in phytotherapy and cosmetology for enhancing skin regeneration. Additionally, these compounds have been shown to induce positive chemotaxis in symbiotic bacteria such as Pseudomonas putida, indicating a microbiome-modulating effect that may enhance the skin's defense mechanisms. At low concentrations (up to 20 µg/mL), these complexes display biostimulant activity; however, when the concentration exceeds 100 µg/mL, they begin to inhibit growth, likely due to allelopathic effects.

Coltsfoot (*Tussilago farfara*)

Tussilago farfara L., a member of the Asteraceae family, is a widely distributed perennial plant commonly found in temperate zones of Eurasia, including Europe, the Caucasus, Siberia, and the Russian Far East. According to research, in the southern regions of Primorsky Krai it predominantly grows along roadsides, in vacant lots, abandoned orchards, and other anthropogenically disturbed habitats, indicating a tendency for naturalization primarily in artificially transformed ecosystems. At the same time, the plant is actively cultivated and harvested in Bulgaria, where its raw material is used for the analysis of biologically active compounds, highlighting the persistent presence of T. farfara in both pharmaceutical practices and the regional flora.

The chemical composition of Tussilago farfara L. is notably complex and diverse, comprising flavonoids, phenolic acids, terpenoids, alkaloids, and chromones. Contemporary studies have identified over 150 compounds in the plant's leaves, with particularly active constituents

including derivatives of dicaffeoylquinic acid (e.g., compounds 7-12), which exhibit significant inhibitory activity against aldose reductase—an enzyme associated with diabetic complications. Moreover, novel flavonoid glycosides have been isolated, such as kaempferol 3-O-[3,4-O-(isopropylidene)-α-L-arabinopyranoside], reported for the first time in this species. Additional constituents identified in the leaves and floral buds include sesquiterpenes, triterpenoids, chromones, chlorogenic and rosmarinic acids, as well as pyrrolizidine alkaloids, some of which are known to possess toxic properties. This extensive array of secondary metabolites underpins the pharmacological activity of the plant, including its antioxidant, anti-inflammatory, and antidiabetic effects (Figure 6). In modern formulations, these compounds may be combined with auxiliary agents such as de- oxycholic acid—a secondary bile acid with surfactant and lipolytic properties—to improve transdermal delivery and efficacy in pharmaceutical and cosmetic products.

Phytotherapeutic application and chemical composition of Tussilago farfara.

Tussilago farfara L. has long been utilized in both European and Asian traditional medicine for the treatment of dermatological and respiratory disorders. In Traditional Chinese Medicine, the floral buds (Farfarae flos) are primarily used due to their expectorant, antiinflammatory, and soothing properties, which also extend to the treatment of skin irritations, wounds, and acne. Phytochemical studies have confirmed that the major bioactive compounds in the plant include flavonoids, phenolic acids, and sesquiterpenes—particularly tussilagone—which exhibit antioxidant, antimicrobial, and wound-healing activities. In Ayurvedic practice, the plant is also used topically for inflammatory skin conditions and to promote tissue regeneration. Recent studies suggest that T. farfara demonstrates significant anti-inflammatory effects by suppressing the expression of pro-inflammatory cytokines and inhibiting key enzymes involved in skin inflammation.[10]

Aloe vera (Common name: Barbados aloe; Family: Xanthorrhoeaceae)

Aloe vera has shown very good results in skin diseases and it is often taken as health drink. It is also found effective in treating wrinkles, stretch marks and pigmentations. It also seems to be able to speed wound healing by improving blood circulation through the area and preventing cell death around a wound. One of the studies conducted on mice to investigate the effects of Scutellariae radix and Aloe vera gel (AV), in spontaneous atopic dermatitis (AD)-like skin lesions revealed that the group receiving only AV in a dose of 0.8 mg/kg p.o provided relief in AD due to reduction of interleukin (IL)-5 and IL-10 levels. The gel has properties that are harmful to certain types of bacteria and fungi. A cream containing 0.5% aloe for 4 weeks reduced the skin "plaques" associated with psoriasis. Application of gel helped in the improvement of partial thickness burns. When applied to the skin, the gel seems to help skin survive frostbite injury. It might delay the appearance of skin damage during and after radiation treatment.

Aloevera

***Azadirachta indica* (Common name: Neem; Family: Meliaceae)**

Leaf extract is applied externally on boils and blisters. In one study, skin tumors were induced in mice by topical application of DMBA (500 nmol/100 µl for 2 weeks) followed by TPA (1.7 nmol/100 µl of acetone, twice weekly) as a promoter. The test group received aqueous Azadirachta indica leaf extract (AAILE) orally at a dose level of 300 mg/kg body weight three times a week for 20 weeks. The results of this study revealed the chemopreventive potential of A. indica against murine skin carcinogenesis Study designed to determine the modulatory effect of aqueous AAILE on cell cycle-associated proteins during two-stage skin carcinogenesis in mice in which skin tumors were induced by topical application of DMBA as a carcinogen followed by the repetitive application of TPA as a promoter. Skin tumors obtained in the DMBA/TPA group exhibited enhanced expression of

proliferating cell nuclear antigen (PCNA, index of proliferation), p21 and cyclin D1, with no alterations in p53 expression in comparison to the control group. Tumors in AAILE + DMBA/ TPA group exhibited low PCNA and cyclin D1 expression and enhanced expression of p53 and p21 in comparison to the DMBA/TPA group. The skin tumors obtained in the AAILE + DMBA/TPA group exhibited high lipid peroxidation levels in comparison to the tumors obtained in the DMBA/TPA group. The observations of the study suggested that AAILE behaves as a pro-oxidant in the tumors, thereby rendering them susceptible to damage, which eventually culminates into its anti-neoplastic action. Also, cell cycle regulatory proteins may be modulated by AAILE and could affect the progression of cells through the cell cycle.

Another study, conducted on an anti-acne moisturizer formulated from herbal crude extracts and investigated for the physico-chemical parameters as well as antibacterial activity of the formulation, revealed that ethanol extract of Andrographis paniculata, Glycyrrhiza glabra, Ocimum sanctum, A. indica and Green tea possessed the potential for inhibiting acne. It was observed that the optimal formula of anti-acne moisturizer was satisfactorily effective to control acne inducing bacteria i.e., Staphylococcus epidermis and Propionibacterium.

Neem

CONCLUSION

In conclusion, this project highlights that common skin diseases remain a significant public health concern, affecting individuals across all age groups and backgrounds. Conditions such as acne, eczema, fungal infections, and psoriasis not only impact physical health but also influence psychological well-being and quality of life. Early recognition and accurate diagnosis are essential for effective management and prevention of complications. Advances in dermatological therapies, including topical, systemic, and biologic treatments, have

improved patient outcomes considerably. Patient education, hygiene practices, and lifestyle modifications play a crucial role in long-term disease control. Furthermore, accessibility to healthcare services and awareness programs can help reduce disease burden, especially in underserved populations. A multidisciplinary approach involving clinicians, patients, and caregivers ensures better adherence and holistic care. Continued research and innovation are necessary to develop more effective and affordable treatments. Overall, timely intervention and comprehensive management strategies are key to minimizing the impact of common skin diseases.

REFERENCES

1. Prof. Nahida Tabassum, Department of Pharmaceutical Sciences, Pharmacology Division, University of Kashmir, Hazratbal, Srinagar - 190 006, Jammu and Kashmir, India.
2. Vichitra Sukumaran Advanced trainee and Sanjaya Senanayake Senior specialist Associate professor of medicine, Bacterial skin and soft tissue infections, Infectious Diseases Canberra Hospital Australian National University Medical School Canberra, OCTOBER 2016; 39.
3. Bisai A, Tandi Dy, Singh V, Kumar N, Sahu Gk and Sharma H, The Role of Herbal Medicines for Treatment of Fungal Infections: A Systematic Review, Rungta Institute of Pharmaceutical Sciences & Research, Kohka, Kurud, Bhilai, Intrnational Journal of Biology, Pharmacy and Allied Sciences, [IJBPAS], January, 2025; 14(1): 215-227.
4. Vishva Khunt, Pooja Khanpara, Sanjay Vyas and Dr. Shital Faldu, A REVIEW: NATURAL REMEDIES FOR ANTI-ACNE THERAPY World Journal of Pharmaceutical Research, 07 Nov. 2023; 12(20): 414-437.
5. Muhammad Herdianto Hanindyo 1, and Brian Eka Rachman. The role of antibiotics in the treatment of bacterial infections: A literature review. Magna Scientia Advanced Research and Reviews, 2024; 12(02): 410-413 Publication history: Received on 03 November 2024; revised on 18 December 2024; accepted on 20 December 2024.
6. Dara Grennan, MD; Christy Varughese, PharmD, BCIDP, MSc; Nicholas M. Moore, PhD. Rush University Medical Center, Chicago, Illinoison. Medications for Treating Infection, Volume 323, Number 1, JAMA January 7, 2020.
7. Rukesh Kumar Sharma, Parul Verma, Kiran Bala, Ajeet Pal Singh &Amar Pal Singh. Antifungals:Effective Treatments for Fungal Infections, International Journal of Pharmaceutical Research and Applications, 10(2): 587-1602.

8. Madhura Roy, Sonali Karhana, Md Shamsuzzaman, Mohd. Ashif Khan Recent drug development and treatments for fungal infections Brazilian Journal of Microbiology, 23 May 2023.
9. Victoria Susan, Mylène Lang, Marcela Sabou and Line Bourel-Bonnet, Antifungal Drugs for the Treatment of Invasive Fungal Infections—A Limited Therapeutic Toolbox Facing Growing Resistances Chemobiology and Pharmacognosy for Health (CPS) Team, Strasbourg Institute for Drug Discovery and Development (ITI IMS), Laboratory of Therapeutic Innovation (LIT), UMR 7200 CNRS/Unistra, Faculty of Pharmacy, 74, Route du Rhin, 67400 Illkirch, France, University of Strasbourg Institute for Advanced Studies (USIAS), 67000 Strasbourg, France.
10. Nazerke Bolatkyzy, Daniil Shepilov, Rakhymzhan Turmanov, Dmitriy Berillo, Tursunay Vassilina, Nailya Ibragimova, Gulzat Berganayeva, and Moldyr Dyusebaeva, Medicinal Plants for Skin Disorders: Phytochemistry and Pharmacological Insights, Faculty of Engineering and Information Technologies, Kazakh-German University (DKU), 2025; 30: 3281.
11. Prof. Nahida Tabassum, Department of Pharmaceutical Sciences, Pharmacology Division, University of Kashmir, Hazratbal, Srinagar - 190 006, Jammu and Kashmir, India.
12. Rohit Yadav, Saurabh Rajvaidhya, Ajay Samnani. Review on Antioxidants and its Evaluation. World Journal of Pharmaceutical Research, 2012; 1(2): 41-58.