



Review Article

Role of Natural Antimicrobial Agents in Management of Eczema

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ABSTRACT

Eczema, clinically referred to as atopic dermatitis, is a chronic inflammatory skin disorder characterized by pruritus, erythema, dryness, and recurrent microbial infections. The condition is frequently associated with colonization by pathogenic microorganisms, particularly *Staphylococcus aureus*, which contributes to disease exacerbation and persistence. Conventional therapeutic approaches, including topical corticosteroids and antibiotics, provide symptomatic relief but are often limited by adverse effects and the emergence of antimicrobial resistance upon prolonged use. In recent years, natural antimicrobial agents derived from medicinal plants have gained considerable attention as alternative or adjunct therapies in eczema management. These agents, including essential oils, plant extracts, and bioactive phytochemicals, exhibit broad-spectrum antimicrobial, anti-inflammatory, antioxidant, and skin barrier-enhancing properties. Compounds obtained from plants such as *Azadirachta indica*, *Aloe vera*, and *Curcuma longa* have demonstrated significant therapeutic potential in reducing microbial load and alleviating inflammation.

INTRODUCTION

Eczema, commonly referred to as Atopic Dermatitis, is a chronic, relapsing inflammatory skin disorder characterized by intense itching (pruritus), erythema, dryness, scaling, and skin barrier dysfunction. It is one of the most prevalent dermatological conditions worldwide, affecting a significant proportion of both pediatric and adult populations. The global incidence of eczema has increased substantially over the past few decades,

particularly in urban and industrialized regions, indicating the influence of environmental and lifestyle factors on disease development.



Fig no 1 : Eczema

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The pathogenesis of eczema is complex and multifactorial, involving genetic predisposition, immune system dysregulation, environmental triggers, and microbial imbalance. A key feature of eczema is impairment of the skin barrier, which leads to increased transepidermal water loss and enhanced penetration of allergens, irritants, and pathogens. This barrier dysfunction is often associated with mutations in structural proteins such as filaggrin, resulting in compromised skin integrity and heightened sensitivity.

Microbial colonization plays a crucial role in the progression and exacerbation of eczema. Among various microorganisms, *Staphylococcus aureus* is predominantly associated with eczema lesions and is detected in a large percentage of affected individuals. This bacterium contributes to disease severity by producing toxins, enzymes, and biofilms that trigger inflammatory responses and impair skin healing. Additionally, reduced microbial diversity on the skin further disrupts the natural defense mechanisms, making the skin more susceptible to infections.

Conventional management of eczema primarily includes the use of topical corticosteroids, calcineurin inhibitors, emollients, and systemic therapies in severe cases. While these treatments are effective in controlling symptoms, their long-term use is often limited by adverse effects such as skin atrophy, irritation, and the development of antimicrobial resistance. Furthermore, the recurrence of symptoms after discontinuation of therapy highlights the need for safer and more sustainable treatment approaches. In recent years, there has been growing interest in the use of natural antimicrobial agents derived from medicinal plants for the management of eczema. These agents include essential oils, plant extracts, and bioactive phytochemicals that possess a wide range of pharmacological properties, such as

antimicrobial, anti-inflammatory, antioxidant, and wound-healing activities. Medicinal plants like *Azadirachta indica*, *Aloe vera*, and *Curcuma longa* have been traditionally used in dermatological conditions and have demonstrated promising efficacy in reducing microbial load and improving skin health.

Natural antimicrobial agents offer several advantages over conventional therapies, including better safety profiles, reduced side effects, and lower risk of resistance development. Moreover, their multi-targeted mechanisms of action make them suitable for addressing the complex pathophysiology of eczema. However, challenges such as variability in composition, lack of standardization, and limited clinical evidence still need to be addressed. Therefore, this review aims to provide a comprehensive overview of the role of natural antimicrobial agents in the management of eczema, focusing on their mechanisms of action, therapeutic potential, advantages, and limitations. The study also highlights the need for further research to validate their clinical efficacy and to develop standardized formulations for effective and safe use.

Eczema represents a heterogeneous group of inflammatory skin conditions, among which Atopic Dermatitis is the most common and clinically significant form. The disease is marked by chronic relapsing episodes that significantly impair the patient's quality of life due to persistent itching, sleep disturbances, and psychological stress. In recent years, eczema has been increasingly recognized not only as a localized skin disorder but also as a systemic condition associated with immune imbalance and altered host-microbe interactions. One of the critical aspects of eczema pathogenesis is the disruption of the cutaneous microbiome. Healthy skin maintains a balanced microbial ecosystem that plays a

protective role against pathogenic invasion. However, in eczema patients, this balance is disturbed, leading to dominance of pathogenic organisms, particularly *Staphylococcus aureus*. This microbial imbalance contributes to inflammation through the release of exotoxins, superantigens, and proteolytic enzymes, which further damage the skin barrier and perpetuate the disease cycle. Another important factor in eczema progression is oxidative stress. Increased production of reactive oxygen species (ROS) in the skin leads to cellular damage, lipid peroxidation, and amplification of inflammatory pathways. This highlights the importance of therapeutic agents that possess both antimicrobial and antioxidant properties to effectively manage the condition.

Conventional treatment strategies mainly focus on suppressing inflammation and controlling infection. While these approaches are effective in the short term, they do not address the underlying causes such as microbial imbalance and oxidative stress. Moreover, prolonged use of antibiotics can disrupt normal skin flora, while corticosteroids may lead to adverse dermatological effects. These limitations have driven the search for alternative therapies that are safer and more holistic in their action.

Natural antimicrobial agents have emerged as promising candidates in this context due to their broad-spectrum activity and multi-functional therapeutic effects. Unlike synthetic drugs that often target a single pathway, natural compounds act on multiple biological targets simultaneously. For instance, plant-derived substances such as *Azadirachta indica* and *Curcuma longa* exhibit antimicrobial, anti-inflammatory, and antioxidant activities, thereby addressing several aspects of eczema pathophysiology in a synergistic manner. Similarly, *Aloe vera* contributes to skin hydration

and wound healing, which are essential for restoring barrier integrity.

Pathophysiology of Eczema

Eczema, particularly Atopic Dermatitis, is a multifactorial disorder involving a complex interaction between genetic, immunological, environmental, and microbial factors. The disease progression is driven by a cycle of skin barrier disruption, immune activation, and microbial colonization.

1. **Skin Barrier Dysfunction:** The outermost layer of the skin (stratum corneum) acts as a protective barrier. In eczema

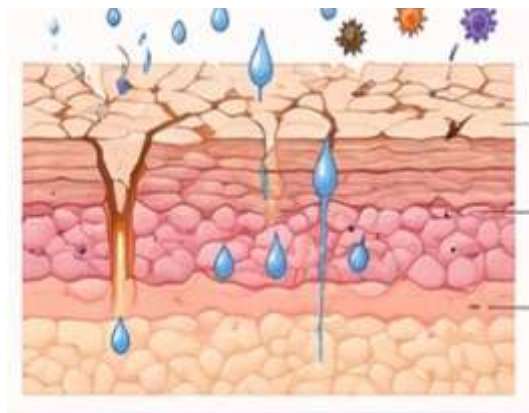


Fig no 2: Skin Barrier Dysfunction

- There is reduced expression of structural proteins such as filaggrin
- Increased transepidermal water loss (TEWL) occurs
- Skin becomes dry, cracked, and permeable

This defective barrier allows allergens, irritants, and microbes to penetrate easily, initiating inflammation.

2. **Genetic Factors :** Mutations in the filaggrin (FLG) gene are strongly associated with eczema ,Genetic predisposition leads to

impaired skin barrier and increased sensitivity , Family history increases susceptibility

3. Immune Dysregulation : Eczema is characterized by an abnormal immune response:

- Dominance of T-helper 2 (Th2) cells
- Increased production of cytokines such as IL-4, IL-5, and IL-13
- Elevated IgE levels

This immune imbalance leads to chronic inflammation and hypersensitivity reactions.

4. Microbial Colonization : The skin microbiome is altered in eczema

- Increased colonization by *Staphylococcus aureus*
- Production of toxins and superantigens
- Biofilm formation that resists immune defense

These factors worsen inflammation and delay healing.

5. Inflammatory Cascade : Activation of immune cells releases inflammatory mediators, Cytokines and chemokines recruit more immune cells, Leads to redness (erythema), swelling, and itching, Persistent inflammation results in chronic skin damage.

6. Itch–Scratch Cycle : Intense itching (pruritus) is a hallmark symptom, Scratching damages the skin further, This increases allergen entry and infection risk, This vicious cycle perpetuates the disease.

7. Environmental Triggers : External factors can exacerbate eczema

- Allergens (dust mites, pollen)
- Irritants (soaps, detergents)
- Climate changes (dry or cold weather)
- Stress

Role of Microorganisms in Eczema :

Microorganisms play a crucial role in the development, progression, and exacerbation of eczema, particularly Atopic Dermatitis. The skin normally hosts a diverse microbiota that protects against pathogenic invasion; however, in eczema, this balance is disrupted, leading to microbial dysbiosis.

1. Colonization by Pathogenic Bacteria : The most significant microorganism associated with eczema is *Staphylococcus aureus* Found in 70–90% of eczema lesions Adheres easily to damaged skin and proliferates rapidly

2. Production of Toxins and Superantigens

- *S. aureus* produces: Enterotoxins, Exotoxins, Superantigens
- These substances: Activate T-cells abnormally, Trigger excessive immune response, Increase inflammation

3. Biofilm Formation : Microorganisms form biofilms on the skin surface, Biofilms Protect bacteria from immune system and drugs ,Lead to persistent and chronic infections, Reduce treatment effectiveness

4. Disruption of Skin Microbiome : Healthy skin contains beneficial microbes like: *Staphylococcus epidermidis* ,



In eczema:

- Decrease in beneficial bacteria
 - Overgrowth of pathogenic microbes
 - This imbalance weakens natural defense mechanisms
5. Induction of Inflammation : Microbial components activate immune cells Release of cytokines and inflammatory mediators Leads to:
- Redness (erythema)
 - Swelling
 - Itching
6. Aggravation of Itch–Scratch Cycle : Microbial toxins increase itching Scratching: Damages skin further ,Facilitates more microbial entry, This creates a vicious cycle
7. Role of Other Microorganisms : Fungi such as *Malassezia* may contribute to eczema, especially in adults Viruses (e.g., herpes simplex) can cause complications like eczema herpeticum

Natural Antimicrobial Agents

Natural antimicrobial agents are bioactive substances derived from plants, microorganisms, and natural sources that inhibit the growth of pathogenic microbes. These agents have gained significant attention in the management of skin disorders like Atopic Dermatitis due to their safety, multi-targeted action, and minimal side effects.

Classification of Natural Antimicrobial Agents

1. Plant-Derived Agents : These are the most widely used natural antimicrobials in dermatology:
 - *Azadirachta indica* (Neem) : Broad-spectrum antibacterial and antifungal activity, Effective against *Staphylococcus aureus*.
 - *Aloe vera* : Soothing, antimicrobial, and wound healing , Enhances skin hydration
 - *Curcuma longa* (Turmeric) : Contains curcumin, Strong anti-inflammatory and antimicrobial properties
2. Essential Oils : Highly concentrated volatile plant extracts:
 - *Melaleuca alternifolia* (Tea Tree Oil) : Potent antibacterial activity, Disrupts microbial cell membranes
 - *Lavandula angustifolia* (Lavender Oil) : Antimicrobial and calming effects, Promotes skin repair
 - *Cocos nucifera* (Coconut Oil) : Rich in lauric acid , Effective against bacteria and fungi
3. Phytochemicals : Active chemical constituents responsible for antimicrobial action:
 - Flavonoids → Anti-inflammatory and antioxidant.
 - Tannins → Astringent and antimicrobial
 - Alkaloids → Antibacterial and immunomodulatory



Mechanisms of Action of Natural Antimicrobial Agents

Natural antimicrobial agents act through multiple biological pathways to control infection and

inflammation in conditions like Atopic Dermatitis. Their multi-targeted mechanisms make them effective in managing both microbial load and skin damage.

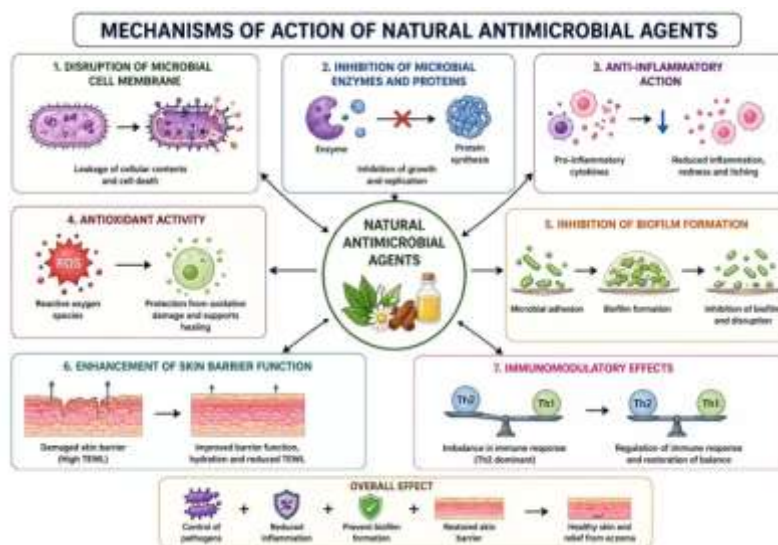


Fig no 3 : MOA of natural antimicrobial agents

- 1. Disruption of Microbial Cell Membrane :** Natural compounds penetrate and damage microbial cell walls, Leads to leakage of cellular contents, Causes death of pathogens such as *Staphylococcus aureus*
- 2. Inhibition of Microbial Enzymes and Proteins :** Interfere with enzyme systems essential for microbial survival, Inhibit protein synthesis, Prevent growth and replication of microorganisms
- 3. Anti-inflammatory Action :** Suppress production of inflammatory cytokines (IL-4, IL-5, IL-13), Reduce redness, swelling, and itching, Help in calming irritated skin
- 4. Antioxidant Activity :** Neutralize reactive oxygen species (ROS), Prevent oxidative damage to skin cells, Support healing and tissue repair
- 5. Inhibition of Biofilm Formation :** Prevent formation of protective microbial biofilms,

Enhance susceptibility of microbes to treatment, Reduce chronic infection

- 6. Enhancement of Skin Barrier Function :** Promote repair of damaged skin layers, Improve hydration and lipid content, Reduce transepidermal water loss (TEWL)
- 7. Immunomodulatory Effects :** Regulate immune system response, Balance Th1/Th2 activity, Prevent excessive immune reactions

Advantages of Natural Antimicrobials

1. Safer and better tolerated compared to synthetic drugs
2. Lower risk of antimicrobial resistance
3. Multi-targeted action (antimicrobial, anti-inflammatory, antioxidant).
4. Suitable for long-term use.
5. Derived from natural and renewable sources

6. Helps restore normal skin microbiota
7. Supports skin barrier repair in Atopic Dermatitis

Limitations

1. Variability in composition due to natural source differences
2. Lack of standardization in extraction and formulation.
3. Limited clinical and large-scale human studies.
4. Possible allergic or hypersensitivity reactions
5. Stability issues (degradation over time)
6. Lower potency compared to some synthetic antimicrobials. Difficulty in dose optimization

Future Perspectives

1. Development of standardized herbal formulations.
2. Advanced drug delivery systems (nanoemulsions, liposomes, hydrogels)
3. Integration with modern dermatological therapies
4. Increased clinical trials for safety and efficacy validation.
5. Exploration of synergistic combinations of natural compounds.
6. Use of biotechnology for enhanced production of active compounds.
7. Personalized medicine approaches for skin disorders like Atopic Dermatitis

CONCLUSION

Natural antimicrobial agents are effective in managing Atopic Dermatitis by reducing microbes like *Staphylococcus aureus* and controlling inflammation. They are safer, multi-functional, and suitable for long-term use. However, lack of standardization and limited clinical evidence require further research for wider application.

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