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MICROORGANISMS IN AYURVEDIC PARLANCE: A CRITICAL REVIEW AND EXPERIMENTAL EVALUATION OF THE ANTIMICROBIAL POTENTIAL OF SUKSHMA ELA (*ELETTARIA CARDAMOMUM*)

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ABSTRACT

The rise of multi-drug resistant pathogens has generated global interest in traditional medical systems like Ayurveda, where infectious diseases are conceptualized under the framework of *Krimi* (microorganisms) and *Janapadodhwansa* (epidemics). This study presents a critical review of *Krimi* and evaluates the antimicrobial potential of *Sukshma Ela* (*Elettaria cardamomum*), traditionally classified as a potent *Krimighna* agent within the *Eladi Gana*. Seed extracts of *E. cardamomum* were prepared at the Rasa Shala of Government Ayurvedic College, Guwahati, and extracted using Methanol and Ethyl Acetate. These extracts were screened against *Staphylococcus aureus* and *Enterobacter aerogenes* using the agar well diffusion method across a 15% to 100% gradient. While the polar methanolic extract showed no zone of inhibition at any concentration, the ethyl acetate extract demonstrated a potent, concentration-dependent activity. At 100% concentration, the ethyl acetate extract produced significant zones of inhibition against *S. aureus* (23.82 ± 0.07 mm) and *E. aerogenes* (15.10 ± 0.06mm). This selective efficacy is driven by lipophilic monoterpenes (α-terpinyl acetate and 1,8-cineole), which alter the biological habitat (*Prakriti*

Vighata) by disrupting microbial membranes, inhibiting quorum sensing, and priming host-mediated antiviral defenses.

KEYWORDS: *Elettaria cardamomum*, Krimi, Janapadodhwansa, Prakriti Vighata, Ethyl Acetate, Staphylococcus aureus, Enterobacter aerogenes.

INTRODUCTION

The rapid global spread of infectious diseases and the emergence of multi-drug resistant pathogens represent a major public health challenge, placing a severe economic burden on healthcare systems worldwide. While contemporary medicine relies heavily on single-target synthetic antimicrobials, traditional systems like Ayurveda offer a holistic and preventive approach. In the Ayurvedic system, all ancient scholars (*Acharyas*) utilize the term *Krimi* to refer to pathogenic and non-pathogenic organisms. The concept of *Krimi* dates back to the Vedic period, with early references in the *Rigveda* and *Atharvaveda* describing visible and invisible organisms existing throughout the environment—in water, trees, mountains, and living beings.[1]

Unlike modern science, which separates the study of parasitic worms (helminthology) from microscopic pathogens (microbiology), Ayurveda integrates both under the unified concept of *Krimi*. Pathogenic *Krimi* (*Vaikarika* or *Vikaraja*) are classified into *Bahya* (external) and *Abhyantara* (internal) varieties. The external *Krimi*, such as *Yuka* (lice) and *Pippalika* or *Liksha*, arise from accumulated dirt and sweat (*Mrijaverjanam*), residing on the skin, hair, and clothing. Internal *Krimi* are sub-classified into three groups based on their tissue of origin and anatomical habitat: *Raktaja* (originating in the blood), *Kaphaja* or *Shleshmaja* (originating in mucus and body fluids), and *Purishaja* (originating in feces).

Table I - Ayurvedic Classical reference of Krimi.

Ayurvedic Samhita (Classical Text)	Enumerated Count of Krimi Types	Key Distinct Classifications and Observations
Charaka Samhita	20	Categorizes into *Sahaja* (non-pathogenic) and *Vikaraja* (pathogenic); further divides pathogenic into 2 *Bahya* and 18 *Abhyantara* (*Raktaja*[6], *Sleshmaja*[7], *Purishaja*[5])
Sushruta Samhita	20	Classifies internal *Krimi* into *Drishya* (visible: *Sleshmaja* and *Purishaja*) and *Adrishya* (invisible: *Raktaja*); does not explicitly define a separate *Bahya* category
Ashtanga Hridaya	20	Compiles and reconciles the classification models established by Charaka and Sushruta

Harita Samhita	13	Enumerates a specialized reduced count focusing on primary clinical helminths and ectoparasites
Bhela Samhita	20	Aligns closely with the standard taxonomic counts described in the *Charaka Samhita*
Madhava Nidana	20	Focuses on the diagnostic features (*Nidana*) and clinical progression of twenty *Krimi* types
Sharangadhara Samhita	22	Introduces *Snayuka* (Guinea worm) and *Vranaja* (wound-associated) *Krimi* to the classical taxonomy
Bhavaprakasha	20	Elaborates on the therapeutic properties of aromatic and bitter herbs against twenty *Krimi* types

The clinical progression of *Krimi Roga* involves a complex host-pathogen interaction known as *Samprapti*. Pathogenesis is initiated by predisposing factors (*Nidana*), such as the excessive consumption of sweet (*Madhura*), sour (*Amla*), and heavy (*Guru*) foods, including refined grains (*Pishtanna*), jaggery, milk, curd, fish, and incompatible food combinations (*Viruddha Ahara*). These dietary habits impair the digestive fire (*Agnimandya*), leading to the accumulation of toxic, undigested metabolic byproducts (*Ama Visha*).[2]

This stagnant, damp environment provides the ideal substrate for *Krimi* colonization in the stomach (*Amashaya*) and colon (*Pakvashaya*). The key pathogenetic factors (*Samprapti Ghatakas*) involve a *Tridosha* imbalance, particularly of Kapha, which compromises the integrity of structural tissues (*Dhatus* like *Rasa*, *Rakta*, *Mamsa*, and *Meda*) and circulatory channels (*Srotas* like *Annavaha* and *Raktavaha*).

A significant predisposing clinical condition is *Mridbhakshanajanya Pandu* (anemia induced by clay or soil eating). The ingestion of soil introduces environmental pathogens into the gastrointestinal tract while causing structural dryness (*Rukshata*) in the *Rasa Dhatu*. The undigested clay physically blocks the circulatory channels, impairing tissue nutrition, lowering immunity (*Bala*), and degrading the host's vitality (*Ojas*). This structural compromise transforms the digestive tract into an environment highly favorable to worm infestation and microbial growth, clinically termed *Krimikoshtha*.[3]

On an epidemiological scale, when these infectious agents spread widely, they manifest as *Janapadodhwansa* (mass population devastation or epidemics) and *Sankramaka Roga* (communicable diseases). Although individuals in a community possess different physiological constitutions (*Prakriti*), diets, and ages, they can contract the same infectious pathology simultaneously when shared environmental resources are contaminated. The primary factors of epidemic spread are contaminated air (*Vayu*), water (*Jala*), land (*Desha*),

and seasonal anomalies (*Kala*).

Acharya Sushruta described the exact modes of transmission for these infectious diseases (*Aupasargika Rogas*), including direct skin-to-skin contact (*Gatra Sansparsha*), inhalation of respiratory droplets (*Nihshwasat*), sharing meals (*Sahbhojanat*), sleeping together (*Sahshayya*), and sharing personal items like clothing and ornaments. This transmission route is highly relevant to contemporary contagious diseases such as tuberculosis (*Rajyakshma*), conjunctivitis (*Netrabhishyanda*), cutaneous infections (*Kushta*), and viral pandemics.

To manage these conditions, Ayurveda outlines a three-step therapeutic protocol (*Chikitsa Sutra*).

1. Apakarshana: The immediate physical or manual extraction of the pathogen load from the body. For external *Krimi*, this involves manual removal, while internal pathogens are expelled using therapeutic purification (*Samshodhana* or Panchakarma). This includes *Vamana* (emesis) for Kapha-associated pathogens in the upper gastrointestinal tract, *Virechana* (purgation) to clear the lower bowel, *Shirovirechana* (nasal errhines) for cranial infections, and *Asthapana Basti* (decoction enemas) for colonic pathogens. Highly oleated oil-based enemas (*Anuvasana Basti*) are avoided, as they can nourish and support the growth of the parasites.
2. Prakriti Vighata: The deliberate alteration of the biological environment (*Utpadaka Karana*) supporting the pathogens. This is achieved by administering herbs and dietary formulations that exhibit properties directly opposite to those of the pathogen's substrate (primarily Kapha and feces). Acharya Charaka recommends using substances characterized by bitter (*Tikta*), pungent (*Katu*), and astringent (*Kashaya*) tastes, combined with a hot potency (*Ushna Guna*), to render the host tissues completely inhospitable to microbial life.
3. Nidan Parivarjana: The systematic identification and avoidance of dietary, behavioral, and environmental factors that trigger *Doshic* imbalance and promote microbial colonization.

Among the classical *Krimighna* agents, *Sukshma Ela* (*Elettaria cardamomum*), commonly known as green or lesser cardamom, is highly valued. Classified under the *Swasahara* (dyspnea-relieving) and *Vishaghna* (antitoxic) *Mahakashayas* of the *Charaka Samhita*, and the *Eladi Gana* of the *Sushruta Samhita*, *Sukshma Ela* is prized for its highly aromatic, volatile-rich seeds. While characterized by a cold potency (*Sheeta Virya*), its pungent (*Katu*) and sweet (*Madhura*) tastes, coupled with its light (*Laghu*) and dry (*Ruksha*) qualities, allow

it to pacify all three physiological humors (*Tridosha Hara*).

Crucially, its inclusion in the *Eladi Gana* highlights its role in skin health, displaying potent anti-itching (*Kandughna*), scraping (*Lekhana*), and channel-cleansing (*Twak Shodhana*) properties. While previous literature reports generic organic extracts (acetone/ethanol) inhibiting *S. aureus*, this study evaluates the specific antimicrobial efficacy of *Elettaria cardamomum* using a tailored dual-solvent extraction system (Methanol vs. Ethyl Acetate). This investigation explores its scientific alignment with the principles of *Prakriti Vighata* and *Krimighna* activity.

MATERIAL AND METHODS

Botanical Procurement and Authentication: Fresh seeds of *Sukshma Ela* (*Elettaria cardamomum*) were procured from authenticated commercial sources. Taxonomic identification and botanical authentication of the plant material were performed at the Department of Botany, Guwahati University, Guwahati, Assam.

Preparation of Plant Material: The preparation of plant material was conducted at the Rasa Shala of Government Ayurvedic College and Hospital, Jalukbari, Guwahati, Assam.

1. The useful seeds of *Sukshma Ela* were thoroughly washed with distilled water to remove surface dirt and debris.
2. The samples were subjected to shade drying at room temperature under aseptic conditions until completely moisture-free.
3. Once dried, the plant seeds were ground and crushed using a clean mortar and pestle to convert them into a fine, uniform powder.

Pharmacognostic and Physicochemical quality control: To ensure the purity and standardized quality of the plant material, pharmacognostic investigations were carried out on the fresh seeds of *Sukshma Ela*. This included.

- Macroscopic study: Sensory evaluation of appearance, colour, odor and taste.
- Microscopic study: Transverse segments of the seeds were processed using chloral hydrate solution and appropriate staining reagents, then examined under a trinocular research microscope to identify diagnostic histological markers.
- Quantitative Physicochemical Estimation: Standard parameters including moisture content, total ash, acid-insoluble ash, and extractive values were assessed using 50 g of the prepared powder at the Drug Testing Laboratory (DTL) of Government Ayurvedic

College and Hospital, Guwahati, Assam, in compliance with the guidelines of the British Pharmacopoeia and Ayurvedic Pharmacopoeia.

Solvent Extraction Protocol

The solvent extraction process was conducted at the Indian Institute of Technology (IIT).

Guwahati, Assam.

1. Methanol Extraction: A 30 g portion of the finely powdered *E. cardamomum* seeds was placed in a conical flask and macerated with 300 mL of methanol in a strict 1:10 (w/v) ratio. The cold maceration process was allowed to proceed undisturbed at room temperature for 72 hours.
2. Ethyl Acetate Extraction: Separately, another 30 g portion of the powdered seeds was macerated with 300 mL of ethyl acetate in a 1:10 (w/v) ratio under identical conditions for 72 hours.
3. Filtration and Concentration: After 72 hours, both mixtures were filtered through a clean muslin cloth first, and subsequently through Whatman No. 1 filter paper to completely remove plant debris. The filtrate was concentrated to dryness under reduced pressure and controlled temperature using a Rotary Evaporator (Rotovap) to yield the pure, concentrated extracts.

Preparation of Bacterial Inoculum

The antimicrobial assay was performed against two target bacterial pathogens.

- Gram-positive: *Staphylococcus aureus*
- Gram-negative: *Enterobacter aerogenes*

Bacterial strains were maintained as glycerol stocks for long-term preservation at low temperatures. For experimental use, each strain was subcultured on Luria-Bertani (LB) agar plates (composed of 10 g Tryptone, 5 g Yeast Extract, 10 g Sodium Chloride, and 15 g Agar-agar per 1000 mL of distilled water; final pH 7.5 ± 0.2). Single colonies from the plates were inoculated into separate 50 mL Falcon tubes containing LB broth (10 g of LB broth powder dissolved in 400 mL of distilled water and autoclaved at 121°C for 20 minutes) and incubated overnight at 37°C for 18 - 24 hours in a bacterial shaker incubator at 160 rpm to obtain standardized liquid cultures.

Agar Well Diffusion Assay

The antibacterial efficacy of the extracts was evaluated using the agar well diffusion method:

1. Plate Preparation: Mueller-Hinton Agar (MHA) or LB agar plates were prepared, sterilized via autoclaving at 121°C for 15 minutes, and poured (20 - 25 mL per plate) into sterile Petri dishes to solidify on a level surface.
2. Inoculation: A sterile cotton swab was dipped into the standardized overnight bacterial suspension. The inoculum was spread evenly in three directions across the surface of the agar plates to generate a uniform lawn of bacterial growth.
3. Well Preparation: Using a sterile cork borer, wells of 6 - 8 mm diameter were bored into the agar.
4. Extract Dilution and Loading: The concentrated Methanol and Ethyl Acetate extracts were reconstituted and serially diluted in ethyl acetate to achieve a gradient of concentrations: 15%, 20%, 25%, 30%, 35%, 40%, 50%, 75%, and 100%. The dilution ratios utilized were:

Table II: Extract dilution & Loading.

0%(Control)	0 µL sample + 1000 µL solvent
15% Concentration	150 µL sample + 850 µL solvent
20% Concentration	200 µL sample + 800 µL solvent
25% Concentration	250 µL sample + 750 µL solvent
30% Concentration	300 µL sample + 700 µL solvent
35% Concentration	350 µL sample + 650 µL solvent
40% Concentration	400 µL sample + 600 µL solvent
50% Concentration	500 µL sample + 500 µL solvent
75% Concentration	750 µL sample + 250 µL solvent
100% Concentration	1000 µL sample + 0 µL solvent

Each well was loaded with 50 - 100 µL of the respective extract dilutions.

5. Controls: Positive controls (standard ciprofloxacin) and negative controls (extraction solvent without plant extract) were run concurrently.

6. Incubation: The plates were allowed to stand undisturbed at room temperature for 30 - 60 minutes to permit pre-diffusion of the extracts into the surrounding agar, then incubated in an inverted position at 35 - 37°C for 18 - 24 hours.

7. Measurement: The diameter of each clear zone of inhibition (including the well diameter) was measured in millimeters (mm) using a digital caliper. All assays were performed in triplicate to ensure reproducibility.

RESULTS AND DISCUSSION

Phytochemical Standarization of *Elettaria cardamomum* Extracts.

Phytochemical characterization of *Elettaria cardamomum* extracts reveals a complex profile containing volatile monoterpenes, sesquiterpenes, and non-volatile polyphenolic compounds. Gas chromatography-mass spectrometry (GC-MS) of the green cardamom essential oil (GCEO) shows a high concentration of oxygenated monoterpenes, representing up to 88.7% of the total composition. The major volatile compounds identified are α-terpinyl acetate and 1,8-cineole.

High-performance liquid chromatography (HPLC) of the ethanolic extract of *E. cardamomum* (EEC) reveals the presence of important non-volatile polyphenolic acids and flavonoids, which contribute to its therapeutic and antioxidant actions.

Table III: Phytochemical Standarization of Elettaria cardamomum Extracts.

Peak Class	Bioactive Phytochemical Component	Typical Quantitative Range / Yield	Associated Pharmacological Action
Oxygenated Monoterpenes	alpha-Terpinyl Acetate	33.07% - 54.46%	Lipophilic membrane permeabilization, AChE inhibition, anti-inflammatory
Oxygenated Monoterpenes	1,8-Cineole (Eucalyptol)	10.70% - 36.74%	Cell membrane disruption, STING-mediated antiviral induction, cytokine regulation
Monoterpene Hydrocarbons	beta-Pinene	5.98%	Synergistic cell wall penetration, antimicrobial activity
Oxygenated Monoterpenes	Linalyl Acetate	5.60% - 8.42%	Anti-inflammatory and synergistic membrane disruption
Oxygenated Monoterpenes	Linalool	3.97% - 5.20%	Destabilization of cytoplasmic membranes, antifungal action
Polyphenolic Acids	Rosmarinic Acid, Caffeic Acid, Ferulic Acid	Present in EEC	Free radical scavenging, anti-inflammatory, antimicrobial synergy
Flavonoids	Kaempferol, Chrysin, Galangin, Pinocembrine, Quercetin	Present in EEC	Direct enzyme inhibition, antioxidant, suppression of inflammatory pathways

This complex volatile and non-volatile matrix targets multiple bacterial structures and pathways simultaneously, preventing the rapid development of microbial resistance.

In Vitro Antibacterial Efficacy of Methanolic vs. Ethyl Acetate Extracts.

To scientifically analyze the *Krimighna* potential of *Sukshma Ela*, the first phase of this study involved a qualitative evaluation of the extraction solvent system (Methanol vs. Ethyl Acetate) against *S. aureus* and *E. aerogenes*.

Table IV: In Vitro Antibacterial Efficacy of Methanolic vs. Ethyl Acetate Extracts.

Sl. No.	Plant Species	Solvent Type	Concentration (%)	Test Organism	Observation (Zone of Clearance)	Interpretation
1	Sukshma ela	Ethyl acetate	20, 25, 30, 35	Staphylococcus aureus	Small but distinct zone of inhibition	Minimal zone of clearance
2	Sukshma ela	Ethyl acetate	50, 75, 100	Staphylococcus aureus	Clear zone of inhibition seen	Maximum zone of clearance
3	Sukshma ela	Ethyl acetate	20, 25, 30, 35	Enterobacter aerogenes	Small but distinct zone of inhibition	Minimal zone of clearance
4	Sukshma ela	Ethyl acetate	50, 75, 100	Enterobacter aerogenes	Clear zone of inhibition seen	Maximum zone of clearance
5	Sukshma ela	Methanol	20, 25, 30, 35	Staphylococcus aureus	No zone of inhibition seen	No zone of clearance
6	Sukshma ela	Methanol	50, 75, 100	Staphylococcus aureus	No zone of inhibition seen	No zone of clearance
7	Sukshma ela	Methanol	20, 25, 30, 35	Enterobacter aerogenes	No zone of inhibition seen	No zone of clearance
8	Sukshma ela	Methanol	50, 75, 100	Enterobacter aerogenes	No zone of inhibition seen	No zone of clearance

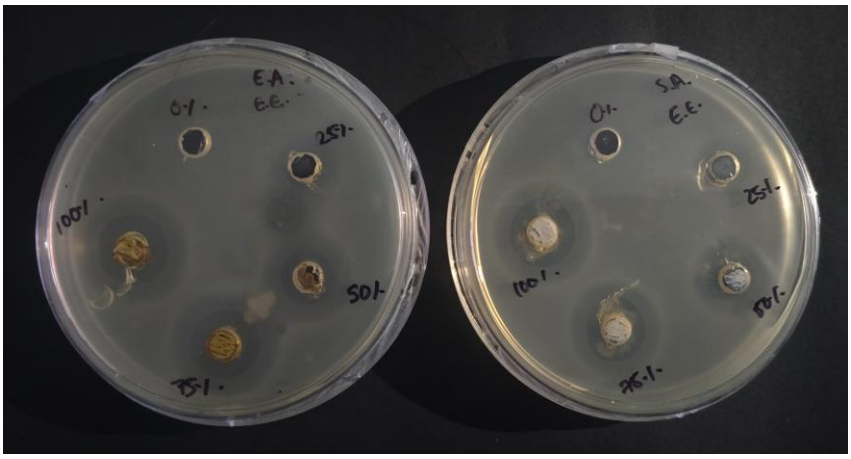

Fig: In vitro antibacterial activity of ethyle acetate extracts of Sukshma ela against *S. aureus* and *E. aerogenes*.

These qualitative findings confirm that Methanol extracts of *Sukshma Ela* are completely inactive, showing 0.00 mm zones of clearance at all concentrations. Conversely, the Ethyl Acetate extract demonstrates potent, concentration-dependent activity, moving from weak minimal clearance at lower concentrations to maximum zones of clearance at higher concentrations.

Table V: Quantitative Profling of Sukshma Ela Extract.

Plant Extract	Concentration	Gram-positive (S.	Gram-negative (E.

	(%)	aureus) ZOI (mm)	aerogenes) ZOI (mm)
Elaichi (*Elettaria cardamomum*)	15%	0.00	0.00
Elaichi (*Elettaria cardamomum*)	20%	10.17 ± 0.16	0.00
Elaichi (*Elettaria cardamomum*)	25%	11.60 ± 0.21	0.00
Elaichi (*Elettaria cardamomum*)	30%	13.00 ± 0.26	0.00
Elaichi (*Elettaria cardamomum*)	35%	14.07 ± 0.13	10.58 ± 0.35
Elaichi (*Elettaria cardamomum*)	40%	14.82 ± 0.14	11.48 ± 0.28
Elaichi (*Elettaria cardamomum*)	50%	16.85 ± 0.19	11.88 ± 0.08
Elaichi (*Elettaria cardamomum*)	75%	16.90 ± 0.17	12.53 ± 0.30
Elaichi (*Elettaria cardamomum*)	100%	23.82 ± 0.07	15.10 ± 0.06

Quantitative Profling of Sukshma Ela Extract

The quantitative antimicrobial effects of *Sukshma Ela* (*Elettaria cardamomum*) Ethyl Acetate extract was profiled across the evaluated concentration gradient (15% to 100%) against both Gram-positive and Gram-negative pathogens.

Analysis of Quantitative Experimental Findings of Sukshma Ela:

The quantitative data reveals a highly significant antimicrobial profile for *Sukshma Ela*:

1. Efficacy Against Gram-Positive *Staphylococcus aureus*: At 100% concentration, *Sukshma Ela* exhibited highly pronounced bactericidal potency, producing a zone of inhibition of 23.82 ± 0.07 mm. Furthermore, it displayed a low initiation threshold of activity, showing a significant zone of clearance of 10.17 ± 0.16 mm at a low concentration of 20%, which steadily increased across the gradient.
2. Efficacy Against Gram-Negative *Enterobacter aerogenes*: Against Gram-negative *E. aerogenes*, *Sukshma Ela* produced a zone of 15.10 ± 0.06 mm at 100% concentration.

Notably, Gram-negative bacteria possess a complex outer lipopolysaccharide membrane that acts as a physical barrier to many hydrophobic drug substances. The initiation of Gram-negative inhibition occurred at 35% (10.58 ± 0.35 mm), showing that a threshold concentration of volatile monoterpenes is necessary to successfully permeabilize the complex Gram-negative outer envelope.

This performance supports the classical placement of *Sukshma Ela* within the *Eladi Gana* and its designation as a premier *Krimighna* agent. Its therapeutic action relies on its lipophilic monoterpenes (α-terpinyl acetate and 1,8-cineole) which are concentrated and stabilized in the moderately polar Ethyl Acetate solvent, allowing them to rapidly disrupt microbial cell walls, cause metabolic depletion, and act as a highly effective agent of *Prakriti Vighata*.[4]

Gastrointestinal and Antispasmodic Activities.[5]

The clinical application of *Sukshma Ela* in gastrointestinal disorders, including diarrhea, flatulence, and colic, is supported by in vivo animal models. The essential oil of Indian cardamom (EC-I) was compared with Guatemalan cardamom oil (EC-G) in a castor oil-induced diarrhea model in mice.

At oral doses of 100 mg/kg and 200 mg/kg, EC-I provided 40% and 80% protection against diarrhea, respectively, compared to 20% and 60% protection for EC-G.

In vitro experiments using isolated rat ileum preparations further confirmed these antispasmodic effects. Both EC-I and EC-G produced dose-dependent inhibition of carbachol (CCh)- and high potassium (k^+) induced contractions. In CCh-mediated spasms, EC-I showed complete inhibition with a significantly lower half-maximal effective concentration (EC_{50} of 0.76 mg/mL) than EC-G (EC_{50} of 4.22 mg/mL). Against potassium-induced contractions, EC-I also displayed higher potency (EC_{50} of 0.08 mg/mL) compared to EC-G (EC_{50} of 0.24 mg/mL).

These findings show that *E. cardamomum* essential oil acts as an effective smooth muscle relaxant. This antispasmodic and hypermotility-reducing activity supports its classical classification as a *Vatanulomana* (gas-regulating and colic-relieving) agent, helping to restore normal gastrointestinal function during infection.

Immunomodulatory, Antiviral and Metabolic Activities.[6]

A During acute infection, the host's inflammatory response can trigger a cascade of tissue damage. In vitro models demonstrate that *Elettaria cardamomum* extracts exert potent anti-inflammatory effects by modulating the signaling pathways of innate immunity.

These anti-inflammatory and cellular protective effects are supported by clinical trials evaluating the systemic metabolic impact of cardamom supplementation. In a randomized clinical trial of obese or overweight pre-diabetic women, daily supplementation of 3 grams of cardamom for 2 months (10 weeks) led to a significant reduction in systemic lipids and inflammatory markers.

These significant reductions in circulating lipids, hs-CRP, and malondialdehyde (a marker of lipid peroxidation) demonstrate that cardamom modulates systemic inflammation and

oxidative stress in human subjects. This systemic action supports its classical Ayurvedic classification as a *Vishaghna* (antitoxic and cytoprotective) agent that purifies structural tissues and circulatory channels (*Srotas*).

Integration with Classical Ayurvedic Formulations.

To understand the clinical utility of *Sukshma Ela*, it is essential to analyze how it is integrated into classical Ayurvedic formulations. These traditional preparations often pair cardamom with other herbs or vehicles to enhance its bioavailability and target specific tissues.

One of the most notable traditional applications of *Sukshma Ela* is in the treatment of *Timira* (visual impairment or cataracts) and localized cranial infections. Classical texts instruct that fine *Ela* powder be immersed in *Basta Mutra* (goat urine) for three consecutive days to undergo *Bhavana* (wet levigation).

The resulting dried, medicated powder is applied as a *Churnanjana* (collyrium) to the conjunctival sac. Goat urine, which contains high concentrations of urea, electrolytes, and bioactive compounds, acts as a highly penetrative organic vehicle. It facilitates the ocular absorption of the lipid-soluble monoterpenes in *Ela*, delivering them directly to the ocular tissues to treat localized *Krimi* and resolve tissue stagnation.

For dermatological and systemic conditions, *Sukshma Ela* is the signature ingredient of *Eladi Thailam*, a classical medicated oil documented in the *Sahasrayogam*. Formulated with the aromatic herbs of the *Eladi Gana*, this oil is traditionally used to manage allergic dermatitis, urticaria (*Sheetapitta*), scabies, acne, and chronic pruritus.

The rich terpenoid and sesquiterpenoid profile of this oil provides anti-itching (*Kandughna*), cleansing (*Twak Shodhana*), and direct antimicrobial (*Krimighna*) effects on the cutaneous epidermis.

Additionally, formulations like *Eladi Ghrita* (medicated ghee) utilize the lipid core of clarified butter to carry the active monoterpenes of *Ela* across the blood-brain and gut barriers, providing systemic relief from abdominal bloating, chronic fevers, and anemia.

CONCLUSION

This critical review and experimental evaluation show a clear alignment between classical Ayurvedic clinical concepts and contemporary pharmaceutical microbiology. The Ayurvedic

concept of *Krimi* provides a highly coherent framework for understanding infectious diseases, while the classical therapeutic principle of *Prakriti Vighata* operates through clear, modern biochemical mechanisms.

The empirical experimental data confirms that *Sukshma Ela* (*Elettaria cardamomum*) is a highly effective, broad-spectrum antimicrobial agent, when prepared using appropriate non-polar organic solvents. The complete inactivity of the Methanol extract contrasted with the concentration-dependent efficacy of the Ethyl Acetate extract indicates that its active antimicrobial constituents—predominantly α-terpinyl acetate and 1,8-cineole—are highly lipophilic.

At higher concentrations (50% to 100%), the ethyl acetate extract directly targets bacterial cell membranes, causing electrolyte leakage and cell death, while also inhibiting quorum sensing and reducing virulence. These findings support the integration of *Sukshma Ela* into modern clinical protocols, offering a safe, effective, and sustainable approach to combating infectious pathogens and overcoming the global challenge of antimicrobial resistance.

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