Research Article

Assessment of Herbal Hydrogels Derived From Cleome Viscosa L. and Boerhavia Diffusa L. Foliage Extracts: Phytochemical Analysis, Rheological Properties, and Antibacterial Efficacy

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Abstract

Topical treatment of bacterial skin diseases increasingly relies on plant-derived bioactive compounds delivered via modern polymer systems. This research comparatively analyses the formulation, physical characteristics, and antibacterial effectiveness of topical hydrogels containing foliage extracts from Boerhavia diffusa L. (family Nyctaginaceae) and Cleome viscosa L. (family Cleomaceae). We shade-dried the collected viable plant foliage and extracted it by cold maceration using polar and non-polar solvents such as petroleum ether, acetone, and ethanol. Initial phytochemical analysis indicated that ethanolic extraction produced the most extensive range of bioactive secondary metabolites for both plant types. We developed two unique hydrogel compositions—Formulation-1 (F1, incorporating ethanolic foliage extract of C. viscosa) and Formulation-2 (F2, incorporating ethanolic foliage extract of B. diffusa)—using Hydroxypropyl Methylcellulose (HPMC K100M) and Carbopol 934 as the gelling polymers. In vitro agar well diffusion assays revealed that both unrefined ethanolic extracts and formulated hydrogels showed significant antibacterial efficacy against dermatological and systemic bacterial pathogens, including Pseudomonas aeruginosa, Staphylococcus aureus, and Klebsiella pneumoniae. In comparison, Formulation-1 (C. viscosa) showed enhanced antibacterial efficacy, with larger zones of inhibition against the examined bacterial strains than Formulation-2 (B. diffusa). Physicochemical and rheological analyses showed that both formulations had stable, physiologically compatible pH levels (5.65 ± 0.020 to 5.72± 0.020), excellent spreadability, pseudoplastic (shear-thinning) flow, complete water solubility, and no skin irritation after 24 hours. In conclusion, Formulation-1 exhibited enhanced antibacterial efficacy and physical stability, confirming C. viscosa ethanolic foliage extract hydrogel as a promising, safe, and effective phytotherapeutic option for topical antibacterial use.

Keywords: C. viscosa L., B. diffusa L., antibacterial, hydrogel, comparative analysis.

1. Introduction

The increasing worldwide prevalence of localised microbial resistance, along with the systemic toxicity frequently linked to traditional synthetic antibiotics, has heightened interest in natural plant-derived bioactive compounds administered using innovative drug delivery systems. Phytotherapeutic compounds offer multifaceted modes of action because of their complex combinations of bioactive secondary metabolites. Nonetheless, topical application of unrefined plant extracts is often limited by poor skin absorption, rapid disintegration, and unsatisfactory physical handling. Hydrogels—three-dimensional, cross-linked networks of hydrophilic polymers—overcome these technical constraints by acting as protective, moisturising, controlled-release matrices that maintain close contact with the stratum corneum. Although researchers have studied certain medicinal plants for topical applications, few comprehensive comparative analyses systematically link solvent extraction efficiency, qualitative phytochemical makeup, rheological flow characteristics, and antibacterial efficacy within the same gel matrices. This study offers an extensive comparative analysis of hydrogels infused with ethanolic foliage extracts from Cleome viscosa L. and Boerhavia diffusa L., laying the pharmacognostic and physical groundwork for their prospective clinical application in dermatology.

1.1 Framework of Phytotherapy and Herbal Medicine

Phytotherapy, characterised as the scientifically grounded clinical use of whole plants or their secondary metabolites to enhance health and manage disease, is a core component of natural medicine. Rooted in conventional healthcare methods across cultures worldwide, contemporary phytotherapy aims to translate empirical botanical insights into standardised, evidence-supported medicinal substances. Phytotherapy uses whole-plant extracts rather than isolated compounds, leveraging the therapeutic synergism of multiple constituents, such as alkaloids, flavonoids, tannins, and saponins, to produce pharmacological effects while reducing the risk of microbial drug resistance.(Dilip Ghosh, 2016; Ghosh, 2016)

1.2 Hydrogel Polymers and Pharmaceutical Delivery Mechanisms

Hydrogels are sophisticated drug delivery systems that amalgamate synthetic polymer chemistry, biomaterials science, and pharmaceutical formulation engineering. Hydrogels are chemically characterised as three-dimensional hydrophilic polymer networks stabilised by physical or chemical cross-linking, and they can absorb, retain, and swell with large amounts of water or biological fluids without structural disintegration. The high moisture content provides tissue-like flexibility and improved skin compatibility, making hydrogels well suited for topical, transdermal, and mucosal medicinal applications. (Ahmed, 2015; Rizwan et al., 2021)

1.3 Essential Functional Attributes of Topical Hydrogels

To ensure clinical effectiveness, physical stability, and elevated patient adherence, enhanced topical hydrogel administration systems must meet rigorous functional and quality standards:

• Insignificant Soluble Content and Remaining Monomers: Guaranteeing thorough polymer cross-linking throughout the formulation process to eradicate unreacted chemical entities that may provoke tissue toxicity or cellular inflammation.

• Preservation of Swelling Stability and Network Cohesion: Ensuring exact mechanical resilience, structural swelling balance, and bio-active retention capability amongst fluctuating environmental temperatures and physiological moisture conditions.

• Sensory Acceptability: Ensuring total transparency, absence of scent, non-oily texture, and safety to promote consistent patient compliance throughout prolonged topical treatments.

• Photostability and Chemical Integrity: Withstanding molecular deterioration or oxidative spoilage when subjected to ambient light and heat stress during storage at room temperature.(Rizwan et al., 2021)

1.4 Botanical Overview: Cleome viscosa L.

The genus Cleome encompasses around 427 acknowledged species found worldwide in tropical and subtropical habitats, with seven species having established medicinal applications (Cleome aspera, Cleome chelidonii, Cleome folina, Cleome gynandra, Cleome monophylla, Cleome tenella, and Cleome viscosa). Cleome viscosa L. (Family: Cleomaceae), commonly known as Asian spider blossom or wild mustard, is an upright annual herb reaching 30 to 80 cm. It flourishes as a prevalent weed in barren lands, sandy terrains, rural peripheries, and rocky fissures across India. Conventional medical systems use C. viscosa formulations for their established anti-inflammatory, antipyretic, wound-repairing, antidiarrheal, and broad-spectrum antibacterial properties.(Chopra, 1977)

1.5 Botanical Overview: Boerhavia diffusa L.

Boerhavia diffusa L. (Family: Nyctaginaceae), traditionally known as Punarnava in Sanskrit, is a sprawling perennial plant indigenous to India and found in tropical and subtropical areas up to 2,000 meters elevation in the Himalayas. Commonly called "spiderlings" because of its sprawling, low-lying growth that forms a web-like ground cover, B. diffusa plays a crucial role in traditional Ayurvedic medicine, as evidenced by references in ancient texts such as the Charaka Samhita and Sushruta Samhita. Ethnomedicinal texts record extensive medicinal use of B. diffusa root and foliage formulations to treat bronchial asthma, persistent urinary ailments, leukorrhea, inflammatory joint conditions, and encephalitis.

The unique structural categories of bioactive secondary metabolites produced by these two plants require stringent laboratory extraction methods and accurate incorporation into polymeric matrices to determine their comparative medicinal efficacy. (Madhava Chetty et al., 2008; Parimala Devi et al., 2003)

2. Materials and Methods

Creating repeatable botanical hydrogels requires uniform plant foliage collection, controlled solvent extraction, precise polymer cross-linking, and verified physical and biological assessments. Harmonising maceration parameters ensures consistent secondary metabolite yields, while controlled dual-polymer dispersion ensures uniform matrix viscosity, spreadability, and active-ingredient diffusion vital for clinical use.

2.1 Plant Gathering and Botanical Verification:

Fresh, completely developed foliage of Cleome viscosa L. and Boerhavia diffusa L. was collected from natural populations and specific agricultural areas in Vazhapadi, Salem District, Tamil Nadu, India. Botanical identification and taxonomic verification were conducted by Dr A. Balasubramanian, Executive Director of the ABS Botanical Conservation, Research and Training Centre, and Siddha Research Consultant (AYUSH), located in Salem, Tamil Nadu.

2.2 Maceration Extraction Method

The collected foliage was carefully categorised to remove old, damaged, or disease-infected parts. Pristine specimens were rinsed with deionised water to remove surface impurities and air-dried in a controlled environment at ambient temperature (25 ± 2°C) until brittle. The dried foliage was mechanically processed into a consistent coarse powder using a standardised industrial grinder and stored in airtight, light-resistant glass vessels.





Fig.No:1. Cleome viscosa L. foliage extraction, Boerhavia diffusa L. foliage extraction

Solid-liquid extraction was performed using cold maceration. We individually immersed coarse powder from each plant species in purified solvents with varying polarities: petroleum ether (non-polar), acetone (intermediate polarity), and ethanol (polar). Maceration was carried out for 3 to 7 days at ambient temperature with intermittent manual stirring. All solvents underwent fractional distillation and purification before utilisation. The resulting liquid extracts were filtered through Whatman No. 1 filter paper and condensed under reduced pressure to yield crude extracts for qualitative phytochemical analysis and subsequent hydrogel development. (Azwanida, 2015)

2.3 Development of Herbal Hydrogels (F1 and F2)

Topical herbal hydrogels were synthesised by aqueous dispersion using a dual polymer network of Hydroxypropyl Methylcellulose (HPMC K100M) and Carbopol 934 (gelling agent and viscosity-enhancing matrix polymer). Formulation-1 (F1) included the ethanolic foliage extract of C. viscosa, while Formulation-2 (F2) contained the ethanolic foliage extract of B. diffusa.

Accurately measured amounts of HPMC K100M (0.35 g) and Carbopol 934 (0.35 g) were gradually added to 50 mL of filtered water under continuous mechanical agitation (500 RPM) to ensure thorough polymer hydration and prevent aggregation. Simultaneously, 1.0 g of the desiccated ethanolic foliage extract, along with propyl paraben (as needed) and methyl paraben (0.10 g), was completely dissolved in 2.5 mL of propylene glycol (as a humectant and solubilising co-solvent). The mixture of ethanolic extract and preservative was then added dropwise to the hydrated polymer dispersion while maintaining continuous mechanical agitation. Triethanolamine was added incrementally to neutralise the acidic carboxyl groups of Carbopol 934, facilitating cross-linking and producing a transparent, smooth hydrogel.(Abbas et al., 2023; Nguyen et al., 2024)

Ingredient	Function / Type	Composition Label (% w/w)*	F1 Quantity (g or mL)	F2 Quantity (g or mL)
Cleome viscosa L. Extract	Ethanolic Active Extract	1.00%	1.00 g	—
Boerhavia diffusa L. Extract	Ethanolic Active Extract	1.00%	—	1.00 g

HPMC K100M	Hydrophilic Polymer Matrix	0.35%	0.35 g	0.35 g
Carbopol 934	Synthetic Gelling Agent	0.35%	0.35 g	0.35 g
Methyl Paraben	Antimicrobial Preservative	0.10%	0.10 g	0.10 g
Propylene Glycol	Humectant / Solubilizer	2.50%	2.50 mL	2.50 mL
Propyl Paraben	Antimicrobial Preservative	q.s.	q.s.	q.s.
Triethanolamine	Neutralizing Agent / pH Adjuster	q.s.	q.s.	q.s.
Purified Water	Aqueous Vehicle	q.s. to 50 mL	q.s. to 50 mL	q.s. to 50 mL

Table No. 1: Chemical composition of Herbal hydrogel formulation



Fig.No.2. Formulation Of Herbal Hydrogel of Ethanolic Plant Foliage Extracts

2.4 Protocol for In Vitro Antibacterial Well Diffusion Assay

The antibacterial efficacy of both crude extracts and manufactured hydrogels was assessed utilising the standardised agar well diffusion technique:

1. Inoculum Formulation: Uncontaminated cultures of specific bacterial strains—comprising Gram-positive isolates and Gram-negative isolates were inoculated from stock agar slants into tryptic soy broth (4 to 5 mL) utilising a sterile wire loop. Broth cultures were maintained at 35°C for 2 to 6 hours, until the turbidity reached or exceeded a 0.5 McFarland standard (about 1.5 × 10^8 CFU/mL).

Sterile Mueller-Hinton Agar (MHA) plates were fabricated and allowed to cool to ambient temperature. Fifteen minutes after standardising the inoculum, a sterile cotton swab was immersed in the bacterial suspension. The swab was turned multiple times and pressed hard against the inner wall of the tube above the fluid level to remove surplus liquid. The MHA surface was thereafter streaked equally in three orientations to create a dense, confluent bacterial lawn.

3. Application and Incubation of Wells: Radial wells of 6 mm in diameter were meticulously created in the agar using a sterile cork borer. Crude botanical extracts (dissolved in water or dimethyl sulfoxide [DMSO]) or prepared hydrogels (50 µL and 100 µL) were added to the specified wells. Standardised reference antibiotic disks (Penicillin, Levofloxacin, Ciprofloxacin, Meropenem) were concurrently assessed as positive controls. Inoculated plates were kept at ambient temperature for 30 minutes to promote pre-diffusion of bioactive compounds into the adjacent agar matrix before incubation at 35°C for 24 hours. The antibacterial effectiveness was assessed by measuring the clear zone of inhibition (ZOI) in millimetres (mm) with digital callipers.(Othman et al., 2011)

2.5 Protocols for the Evaluation of Physicochemical and Rheological Properties

• **pH Assessment:** A mass of one gram (1 g) of hydrogel was completely dissolved in 25 mL of deionised water. Potentiometric pH readings were taken at 25°C using a digital pH meter (Systronics Ltd.) pre-calibrated with standard buffer solutions (pH 4.0 and 7.0). Assessments were conducted in duplicate.

• **Dispersibility Assessment:** The spreadability was assessed utilising a dual-slide glass apparatus to quantify slip and

drag properties. A 2 g hydrogel specimen was positioned on a stationary glass plate, topped with an additional glass slide, and subjected to a 100 g weight for 5 minutes to eliminate air bubbles and create a consistent gel layer. Surplus gel was removed from the peripheries. The upper slide was connected to an 80 g weight pan (M) via a non-elastic cord over a low-friction pulley. The duration (T, in seconds) for the upper slide to travel a distance (L = 7.5 cm) on the lower slide was recorded. The calculation of spreadability (S) was performed using the equation:

S=M × L /T

Where, S= Spread ability

M= Weight in pan (tied to upper slide)

L= Length moved by the glass slide

• **Viscosity Assessment:** The rheological characteristics and apparent viscosity were evaluated at 25°C with a Brookfield rotational viscometer fitted with a suitable spindle. Rotational velocities were incrementally adjusted to 10, 20, 30, 50, and 100 RPM. Dial readings were recorded in triplicate after the spindle stabilised at each velocity.

• **Extrudability Evaluation:** Flexible aluminium collapsible tubes were loaded with 20 g of hydrogel and sealed securely. A constant-pressure clamp was fastened at the crimped end to prevent retrograde movement; the cap was removed, and the time to extrude the gel was recorded.

• **Skin Irritancy and Washability Assessments:** A 1 cm² patch area was allocated on the dorsal surface of the hand of healthy participants. Researchers applied a consistent hydrogel layer and evaluated it at regular intervals over 24 hours for erythema, oedema, or skin irritation. Then, later evaluated washability by flushing the application area with flowing tap water.(Islam et al., 2004)

These experimental findings provide a basis for comparing the phytochemical and physical attributes of the two hydrogel formulations.

3. Results and Discussion

A thorough evaluation of herbal hydrogel efficacy requires correlating solvent-extraction selectivity with detectable phytochemical components, antibacterial inhibition zones, and the rheological properties of the polymer matrix. Solvent polarity determines the extraction efficiency of antibiotic secondary metabolites, which in turn influences microbial suppression. The physical interactions between dissolved phytoconstituents and the cross-linked Carbopol-HPMC polymer network determine the hydrogel's viscosity, spreadability, skin compatibility, and dispensing characteristics.

S. NO	PHYTO CHEMICAL CONSTITUENT	IDENTIFICATION TEST	Cleome viscosa L. foliage extract			Boerhavia diffusa L. foliage extract		
			PET. ETHER	ACETONE	ETHANOL	PET. ETHER	ACETONE	ETHANOL
1	**CARBOHYDRATES**	MOLISCH TEST	+	+	+	+	+	+
		BENEDICT TEST	-	-	-	-	-	+
2	**ALKALOIDS**	MAYER'S TEST	+	-	+	-	-	+
		WAGNOR'S TEST	-	+	+	-	+	+
		DRAGONDROFF'S TEST	-	+	+	+	-	+
3	**PROTEINS**	MILLON'S TEST	-	-	+	-	+	+
4	**SAPONINS**	FOAM TEST	+	+	+	+	+	+
5	**STEROIDS**	SALKOWSKI TEST	+	+	-	+	+	-
6	**GLYCOSIDES**	KILLER KILLANI TEST	+	-	+	-	+	+
7	**FLAVONOIDS**	SODIUM HYDROXIDE TEST	+	-	+	+	-	+
8	**TANNINS**	FERRIC CHLORIDE TEST	-	-	+	-	-	+

(-) indicates the absence of phytochemical constituents qualitatively.
(+) indicates the presence of phytochemical constituents qualitatively.

Table. No.2: Preliminary phytochemical screening of plant foliage extracts of Cleome viscosa l and Boerhavia diffusa

The phytochemical screening data show that ethanol yielded a more extensive array of secondary metabolites than petroleum ether or acetone. Ethanol's high dielectric constant and intermediate polarity facilitate the dissolution of hydrophilic polyphenols alongside moderately lipophilic alkaloids. In contrast, non-polar petroleum ether primarily removed lipophilic steroids and saponins, while intermediate acetone showed erratic recovery of polar metabolites. These results support selecting ethanolic leaf extracts as the active medicinal ingredients for hydrogel formulation.

3.2 In-vitro anti-bacterial studies:

The initial agar well diffusion evaluation of crude ethanolic foliage extracts (S1: C. viscosa; S2: B. diffusa) at 200 µL revealed baseline antibacterial activity against standard test pathogens when compared with Penicillin positive controls. The raw ethanolic extract of C. viscosa (S1) consistently inhibited Gram-positive and Gram-negative pathogens, yielding a notable 15 mm zone of inhibition against Pseudomonas aeruginosa, whereas B. diffusa (S2) was completely inactive. In contrast, B. diffusa showed somewhat enhanced efficacy against Streptococcus pyogenes (14 mm vs 12 mm). When embedded in polymeric hydrogels (F1 and F2) and tested at 50 µL and 100 µL volumes, both formulations revealed a dose-dependent antibacterial activity against prominent skin pathogens. The pronounced broad-spectrum antibacterial potency of C. viscosa (F1), compared with B. diffusa (F2)—particularly against formidable Gram-negative organisms like P. aeruginosa—can be clearly attributed to key differences in their phytochemical profiles shown in Table 2. Significantly, C. viscosa in ethanol tested positive for tannins using Ferric Chloride, whereas B. diffusa tested negative. Polyphenolic tannins exhibit significant bactericidal properties by forming hydrophobic and hydrogen-bonded complexes with proteins in the bacterial cell envelope and the peptidoglycans of the cell wall. This interaction destabilises the cell wall, increases plasma membrane permeability, and activates vital membrane-bound enzymes (including ATPases and respiratory chain complexes). Tannin-mediated mechanisms, together with co-extracted flavonoids and alkaloids, produce greater membrane disruption and increased bacterial lethality in Formulation-1

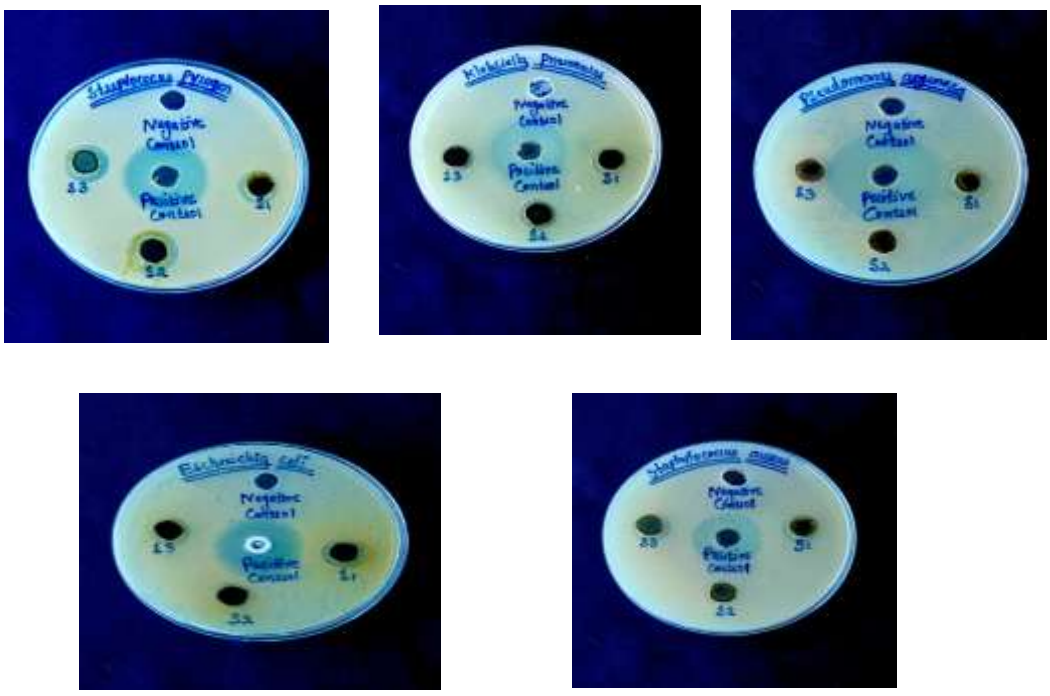


Fig.No.3. Antibacterial Activity of Plant Extracts

S. No	Organisms for test	Zone of inhibition (mm) 200 µl		
		PC (Penicillin)	**S1** (Cleome viscosa L)	**S2** (Boerhavia diffusa L)

1	**Escherichia coli**	26	11	11
2	**Staphylococcus aureus**	27	11	12
3	**Streptococcus pyrogen**	28	14	12
4	**Klebsiella pnumoniae**	29	12	12
5	**Pseudomonas aerginosa**	32	-	15

S1- Cleome viscosa L **Ethanolic foliage extract**
S2- Boerhavia diffusa L **Ethanolic foliage extract**
Table No.3: Antibacterial activity of Plant extracts: Zone of Inhibition

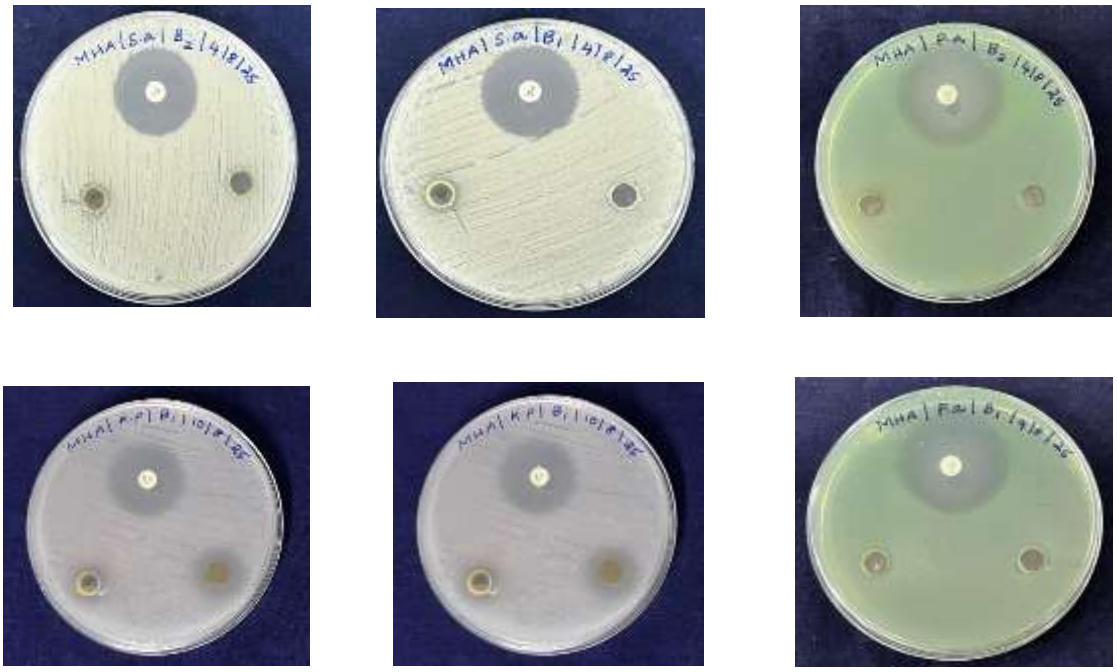


Fig.No.4. Antibacterial activity of herbal hydrogel formulations

Zone of Inhibition (mm)			
Microorganisms	**Antibiotic**	**F1**(B1) **(**Cleome viscosa L)	**F2**(B2) (Boerhavia diffusa L)
Klebseilla pneumonia	Meropenem - 20 mm	50 – 12 mm 100 – 15 mm	50 – 12 mm 100 – 14 mm
Staphylococcus aureus	Levofloxacin - 24 mm	50 – 0 mm 100 – 12 mm	50 – 0 mm 100 – 10 mm

Pseudomonas aeruginosa	Ciprofloxacin - 27 mm	50 – 0 mm 100 – 14mm	50 – 0 mm 100 – 12 mm

F1(B1)- Cleome viscosa L Ethanolic foliage extract Hydrogel formulation
F2(B2)- Boerhavia diffusa L Ethanolic foliage extract Hydrogel formulation

Table No.4: Antibacterial activity of herbal hydrogels: Zone of Inhibition

3.3 Rheological Characterisation:

A. pH

Code of the Sample	pH			pH
	Trial 1	Trial 2	Trial 3	
F1 (Cleome viscosa L Hydrogel)	5.63	5.67	5.65	5.65 ± 0.020
F2 (Boerhavia diffusa L Hydrogel)	5.74	5.70	5.72	5.72 ± 0.020

Table.No.5. pH of herbal hydrogels

B. Spreadability

Batch Code	Weight Applied (g)	Distance Moved (cm)	Time Taken (sec)	Spreadability (g·cm/sec) Triplicate Values	Spreadability (g·cm/sec)
Trial 1	20	7.5	9.5	15.97	15.92 ±0.110
Trial 2	20	7.5	9.4	15.96	
Trial 3	20	7.6	9.5	16.00	

Sample Code: F1(Cleome viscosa L Hydrogel)

Batch Code	Weight Applied (g)	Distance Moved (cm)	Time Taken (sec)	Spreadability (g·cm/sec) Triplicate Values	Spreadability (g·cm/sec)
Trial 1	20	8.0	9.6	16.67	16.63 ±0.035
Trial 2	20	7.8	9.4	16.60	
Trial 3	20	7.9	9.5	16.63	

Sample Code: F2(Boerhavia diffusa L Hydrogel)

Table.No.6. Spreadability of herbal hydrogels(F1 &F2)

C. Viscosity

S.No	RPM	VISCOSITY (mPa.s)
1	100	64.4
2	50	128.8
3	30	161.0
5	20	214.6
6	10	321.9

F1(Cleome viscosa L Hydrogel)

S.No	RPM	VISCOSITY (mPa.s)
1	100	64.5
2	50	128.7
3	30	214.5
5	20	321.8
6	10	643.7

F2(Boerhavia diffusa L Hydrogel)

Table.No.7. Viscosity of herbal hydrogels(F1 & F2)

D. Extrudability

Sample Code	Extra Durability (min)			Extra Durability (min)
	Trial 1	Trial 2	Trial 3	
F1 (Cleome viscosa L Hydrogel)	87	85	86	86.00 ± 1.00
F2 (Boerhavia diffusa L Hydrogel)	90	89	88	89.00 ± 1.00

Table.No.8. Extrudability of herbal hydrogel

E. Irritation assessment:

The entire hydrogel composition caused no skin irritation.

D. Elimination

The entire applied hydrogel composition was effortlessly eliminated when the treated area was rinsed with regular water.

The ethanolic extracts of Cleome viscosa L. and Boerhavia diffusa L. exhibit a broader spectrum of phytochemicals; consequently, their formulations demonstrate enhanced antibacterial properties. F1 showed superior outcomes in pH, viscosity, spreadability, extrudability, and irritancy assessments. Consequently, this hydrogel formulation outperforms F2.

Summary & conclusion:

In this study, we extracted and formulated antibacterial herbal hydrogels using ethanolic foliage extracts of Cleome viscosa L. and Boerhavia diffusa L., and assessed their antibacterial effectiveness. The formulations possess stable pH, viscosity, durability, and spreadability, and can be effortlessly removed upon washing after application. The formulations were non-irritating and did not induce allergic sensitivity concerning skin pH. The extract of Boerhavia diffusa L. and Cleome viscosa L. exhibits antibacterial and antiseptic properties, along with anti-inflammatory effects. Assessment trials showed that the F1 herbal hydrogel formulation (ethanolic foliage extract of Cleome viscosa L.) demonstrated superior efficiency and stability compared with the F2 hydrogel (ethanolic foliage extract of Boerhavia diffusa L.).

The hydrogel formulations effectively inhibited Staphylococcus aureus proliferation, the bacterium responsible for skin infections. The formulated hydrogels exert their effects by impeding bacterial proliferation, hence averting skin infections. Consequently, they generate high antibacterial efficacy. The comparison analysis indicates that the ethanolic leaf extract of Cleome viscosa L. hydrogel (F1) exhibited superior antibacterial properties and safety, demonstrating greater efficacy against skin infections.

Consequently, the extract of Cleome viscosa L. shows greater bacterial inhibition and superior antibacterial activity. The herbal hydrogel formulation (F1), using ethanolic foliage extract of Cleome viscosa L, demonstrates superior antibacterial effectiveness and is more thoroughly assessed than F2 (hydrogel with ethanolic foliage extract of Boerhavia diffusa L).

Ongoing efforts to investigate the mechanisms of antibacterial resistance and to create experimental systems akin to those used in bacteria, where specific resistance mechanisms can be examined, will be crucial to a strategy aimed at curbing the emergence of resistance in these agents and developing safer, more effective compounds for the future.

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Conflicts of interest
There are no conflicts of interest.

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