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Formulation of Antimicrobial Topical Gel Loaded with Stellaria Media Extract

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Abstract

Topical gels prepared from herbal extracts are safer and more efficient than synthetic topical gels. This study is performed to formulate an antimicrobial topical gel made of plant extract Stellaria media. The Stellaria media has many pharmacological activities such as antifungal, anti-inflammatory, anti-leishmanial, and antimicrobial. The extracts of Stellaria media were obtained from maceration, and phytochemical analysis was performed to analyze the phytochemicals present in Stellaria media. The Stellaria media was loaded in the gel base with the gelling agent carbopol-940 and other excipients. Evaluation studies, such as viscosity, pH, spread ability, and homogeneity, were determined. The antimicrobial activity was studied using the disk diffusion method using Gram-positive bacteria (Staphylococcus aureus) and Gram-negative bacteria (Escherichia coli). The zone of inhibition was studied, and the outcomes were comparatively efficient. This implies that Stellaria media-loaded topical gels can be a potential antimicrobial agent.

Keywords: Antimicrobial Activity, Formulation, Natural Extract, Stellaria Media, Topical Gel.

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1. Introduction

Topical drug delivery systems have, in recent years, gained much interest due to the unique property that allows effective local treatment with reduced systemic absorption. Topical gels are preferred because they do not leave a greasy feeling behind, are easy to apply, and facilitate better drug permeation through the skin. Their bioavailability is increased, and there is sustained delivery of the drug, which also improves patient adherence. Unlike ointments and creams, gels possess a three-dimensional polymeric network with an anomalously high capacity for holding large amounts of fluid; this feature enhances drug penetration and controlled release. Their bioavailability is increased, and there is sustained delivery of the drug, which also improves patient adherence (Rathod & Mehta, 2015).

The formulation of antimicrobial topical gel incorporated with herbal extract is novel, efficient, and environmentally benign for treating microbial skin infections and wound healing, which can also act as an alternative to synthetic antibiotics. Stellaria media (chickweed) possesses potential pharmacological activities like antimicrobial, antidiabetic, antileishmanial, and antiobesity, and through the presence of various secondary metabolites such as carbohydrates, proteins, tannins, flavonoids, saponins, and steroids (Oladeji & Oyebamiji, 2020).

This study aims to synthesize a plant-based antimicrobial topical gel incorporated with Stellaria media extract and optimize its physicochemical characteristics, stability, and antimicrobial activity. Formulation preparation includes Carbopol 940 (gelling agent), propylparaben methylparaben (preservatives), and the remaining excipients triethanolamine and propylene glycol to improve its homogeneity and function. The gel is highly characterized at the physicochemical and rheological levels using pH determination, viscosity determination, spread ability tests, freeze-thaw tests, and others to confirm the therapeutic applicability of the gel (Metta, 2023). In addition, in vitro studies are performed to discover the antimicrobial nature of the topical gel loaded with Stellaria media extract against Staphylococcus aureus (Gram-positive bacteria) and Escherichia coli (Gram-negative bacteria) to verify the ability of the gel to restrain bacterial growth. The outcomes of this endeavor have the potential to pave the way for using herbal antimicrobial gels as a substitute for purely synthetic topical agents and OTC topical treatments (Hossain, 2024).

2. Materials and Methods

2.1. *Materials*

Stellaria media (family: Caryophyllaceae) was collected locally, and Staphylococcus aureus and Escherichia coli were used as test microorganisms. Agar medium, ethanol, distilled water, carbopol-940, methyl paraben, propyl paraben, polyethylene glycol, triethanolamine.

2.2. *Methods*

2.2.1. *Preparation of Stellaria media extract*

The extraction procedure is carried out by maceration. The dried leaves and stems of Stellaria media were soaked in the hydro-alcoholic solvent of ethanol and water (50:50). The mixture was soaked for 72 hours with occasional stirring. The liquid, known as menstruum, was then decanted from the mixture. Menstruum was placed on a hot plate at 40–50°C and later placed in a water bath and stirred periodically. A semi-solid substance known as pilular extract is obtained at the end of the extraction process (Kaneria, Kanani, & Chanda, 2012).

2.2.2. *Phytochemical analysis*

The phytochemical test was conducted to screen secondary metabolites in Stellaria media. The series of phytochemical tests were performed according to a standard protocol to identify the secondary metabolites, i.e., flavonoids, tannins, saponins, phenolics, and alkaloids, which are the key pharmacological activities of the plant Stellaria media (Dubale, Kebebe, Zeynudin, & Abdissa, 2023).

2.2.3. *Formulation of gel*

Carbopol 940, being a gelling agent, was mixed with a suitable amount of distilled water and mixed well using a magnetic stirrer. Thereafter, propylene glycol, acting as a humectant, was added to the mixture. Propylparaben and methylparaben were then added to the above formulation. The Stellaria media extract was added, and Triethanolamine was then added to allow the neutralization of the pH. The total weight of the gel was 10 grams. The mixture was stirred at 500 RPM for 2 hours to remove any air bubbles and was left at 32°C temperatures for a day to test its stability and consistency (Chellathurai et al., 2023).

Table 1. Constituents for the Formulation of Gels.

S.NO	INGREDIENTS	QUANTITY	USES
1.	Stellaria media	1%	Anti-microbial
2.	Carbopol940	1%	Gelling agent (synthetic polymer)
3.	Propylparaben	0.1%	Preservative
4,	Methylparaben	0.1%	Preservative
5.	Triethanolamine	0.1%	Emulsifying and neutralizing agent
6.	Propylene glycol	2%	Humectant
7.	Distilled water	Q.s	Vehicle

2.2.4. *Antimicrobial Studies*

The antimicrobial activity of Stellaria media-loaded gel was studied through the disc diffusion technique on Staphylococcus aureus (Gram-positive bacteria) and Escherichia coli (Gram-negative bacteria) (Bonnet, Lagier, Raoult, & Khelaifia, 2020). Test organisms were swabbed on Mueller-Hinton agar plates. An incision was instilled and impregnated with 50 µl of the gel formulation as a test and for control, ofloxacin was used. Petri dishes were incubated at 38°C for 48h, and the antimicrobial activity was assessed for the zone of inhibition (mm). The results were compared with the standard antibiotic to understand whether there are bacterial growth inhibitory activities of the Stellaria media-loaded gel. According to the studies, the herbal gel exhibited the potential antimicrobial activity recorded against the bacterial strains tested, thus confirming its antibacterial property as a topical agent (İşcan, Kirimer, Kürkcüoğlu, Hüsnü Can Başer, & Demirci, 2002).

2.2.5. *Evaluation Studies*

The prepared Stellaria media gel was carefully subjected to a range of physicochemical, rheological, and microbiological tests to guarantee the stability, performance, and safety of the gel for topical use. All these assessment parameters play an important role in identifying the gel/skin compatibility and antimicrobial activity.

- **Organoleptic Properties**: The color, texture, and homogeneity of the gel were assessed to guarantee homogeneity and consistency of appearance.
- **pH Determination**: The pH of the topical gel was determined by a digital pH meter to facilitate its use within the physiological pH range (4.5–6.5) to avoid irritant effects and preserve the skin barrier function.
- **Viscosity Analysis**: Rheological properties were analyzed using a Brookfield viscometer, as viscosity plays a significant role in gel application, retention on the skin, and drug release kinetics. Viscosity was determined at 25 °C in a controlled shear environment to find the spreading and stability characteristics.
- **Spread ability Test**: The spread ability was evaluated using a modified slip-and-drag method. The amount of gel was solidified and fixed between two glass slides under a certain weight and period. Spread diameter was measured to evaluate whether the application has an easy and uniform distribution over the skin.
- **Washability Assessment**: The gel was placed onto the skin and washed off with water to analyze residue formation and ease of washing off, both of which are critical for patient compliance.
- **Grittiness and Homogeneity**: The formulation was examined microscopically to determine if there were any undissolved particles or aggregates, as particulate matter in topical formulations can cause skin irritation. Uniform dispersion of herbal extract and excipient is discussed.

- **Freeze-Thaw Stability**: The gel underwent six freeze-thaw cycles at 5°C, 2°C, and 40°C, 2°C to assess its thermal stability and resistance to phase separation under extreme environmental conditions.
- **Centrifugation Test**: Physical stability under stress conditions was assessed by centrifugation of the gel formulation at 3000 rpm for 30 min. A gel formulation with stability should not show phase separation, sedimentation, or coagulation (Dantas et al., 2016).

3. Result and Discussion

3.1. *Phytochemical analysis*

This study revealed that the Stellaria media extract contains several secondary metabolites, which are listed in the table below. However, the alkaloids and glycosides were not detected in the Stellaria media extract, while the other secondary metabolites are responsible for their antimicrobial activity.

Table 2. Results of phytochemical analysis.

S.NO	TEST	OBSERVATION	INFERENCE
1.	TEST FOR ALKALOIDS Dragendroff test	Formation of an orange-brown precipitate	Absent
2.	TEST FOR CARBOHYDRATE Molisch test	Violet ring at the junction of two liquids	Present
3.	TEST FOR GLYCOSIDES Keller Killiani test	Formation of two layers with the reddish brown Lower layer and bluish-green upper layer	Absent
4,	TEST FOR PROTEINS Xanthoproteic test	Formation of yellow precipitate	Present
5.	TEST FOR STEROIDS Salkowski test	The chloroform layer shows red, and the acid layer shows greenish-yellow	Present
6.	TEST FOR FLAVONOIDS Lead acetate test	Formation of yellow precipitate	Present
7.	TEST FOR SAPONINS Libermann Burchard's test	Color changes from red to green	Present

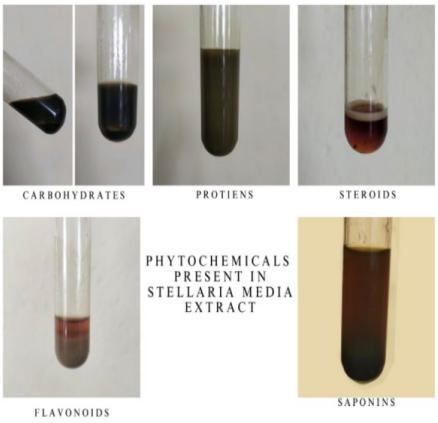

Fig. 1. Phytochemical analysis A.

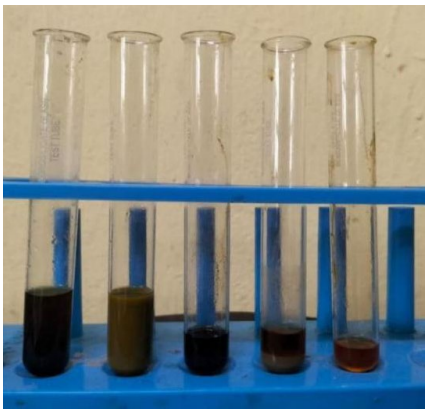

Fig. 2. Phytochemical analysis B.

3.2. *Evaluation of Gel*

Table 3. Evaluation of gel.

S.NO	PARAMETERS	OBSERVATION
1.	COLOUR	OLIVE GREEN
2.	ODOR	CHARACTERISTIC
3.	TEXTURE	SMOOTH
4,	WASHABILITY	WATER WASHABLE
5.	PATCH TEST	NON-IRRITANT
6.	pH	6.9
7.	SPREADABILITY	SPREADABLE
8.	GRITTINESS	NO GRITTY PARTICLES
9.	HOMOGENEITY	HOMOGENOUS
10.	STABILITY	STABLE AT ROOM TEMPERATURE

3.3. *Antimicrobial Test*

The antimicrobial activity was studied using 1% Stellaria media gel, employing the disc diffusion method. The gels were compared to the standard antibiotic, ofloxacin. The zones of inhibition for both the test (1% Stellaria media gel) and standard were evaluated against gram-positive bacteria (Staphylococcus aureus) and gram-negative bacteria(Escherichia coli). For gram-negative bacteria, Escherichia coli was tested, revealing a zone of inhibition of 13 mm for the standard antibiotic and 9 mm for the test gel. For gram-positive bacteria, Staphylococcus aureus was examined, showing a zone of inhibition in the diameters of 15 mm for the standard and 11 mm for the test gel (Miere Groza et al., 2021).

Table 4. Zone of inhibition.

MICROORGANISM	ZONE OF INHIBITION (mm)	
	STANDARD (Ofloxacin)	TEST (Gel loaded with Stellaria media)
Gram-negative bacteria (Escherichia coli)	13 mm	9 mm
Gram-positive bacteria (Staphylococcus aureus)	15 mm	11 mm



Fig. 3. Zone of Inhibition.

4. Conclusion

A topical gel formulated with Stellaria media was successfully prepared, incorporating additives such as polymers and preservatives. The gels demonstrated satisfactory pH, viscosity, spread ability, and stability. Phytochemical analyses revealed that Stellaria media lacks alkaloids and flavonoids. However, it does contain other phytochemicals, including flavonoids, phenols, saponins, steroids, and proteins, which contribute to its pharmacological properties. The Stellaria media gels were evaluated for their antimicrobial activity using the disc diffusion method. As per the results, the Stellaria media gel effectively inhibited the growth of both gram-negative bacteria (Escherichia coli)and gram-positive bacteria (Staphylococcus aureus), indicating its potential antimicrobial activity. Therefore, this formulation could serve as a promising alternative to existing antimicrobial topical or transdermal treatments. Nevertheless, further in vivo studies, clinical trials, and long-term stability assessments are necessary to fully establish its efficacy.

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