Formulate and Evaluate a Hydrogel based Drug Delivery System Containing Green Tea Extract for Wound Healing

Miss. Vaishnavi Dawalbaje[1], Pratiksha Vitthal Chaudhar[2]
[1]*Assistant Professor, Yashodeep Institute of Pharmacy Chh. Sambhajinagar, Maharashtra, India*
[2]*Yashodeep Institute of Pharmacy Chh. Sambhajinagar, Maharashtra, India*

***Abstract*—Hydrogels are three-dimensional polymeric networks capable of retaining large amounts of water and have emerged as promising carriers for wound healing applications. Herbal-based hydrogels are gaining attention due to their biocompatibility, safety, and therapeutic potential. The present project focuses on the formulation and evaluation of a hydrogel-based drug delivery system using green tea extract for wound healing activity.**

Green tea contains polyphenols, catechins, flavonoids, and antioxidants that exhibit antimicrobial, anti-inflammatory, and wound healing properties. In this study, Carbopol 940 was used as the gelling polymer, glycerin as humectant, methyl paraben as preservative, and triethanolamine as neutralizing agent. The hydrogel was prepared by dispersion method followed by incorporation of green tea extract.

The formulated hydrogel was evaluated for various physicochemical parameters such as appearance, pH, viscosity, spreadability, homogeneity, extrudability, and stability. The prepared formulation showed satisfactory consistency, acceptable pH, good spreadability, and smooth texture suitable for topical application.

The study concludes that green tea hydrogel can serve as an effective herbal wound healing formulation with improved patient compliance and enhanced therapeutic activity.

***Index Terms*—Hydrogel, Green Tea Extract, Wound Healing, Carbopol 940, Herbal Drug Delivery System, Topical Gel**

I. INTRODUCTION

Wound healing is a natural and highly coordinated biological process that restores the integrity and function of damaged tissues after injury. It involves a series of overlapping phases including hemostasis, inflammation, proliferation, and remodeling. During the healing process, various cellular activities such as fibroblast proliferation, collagen synthesis, angiogenesis, and epithelialization occur to repair the wounded tissue. Delayed or improper wound healing may lead to infection, chronic wounds, tissue damage, and severe complications. Therefore, effective wound management plays an important role in preventing microbial contamination, reducing inflammation, and accelerating tissue regeneration.

Conventional wound healing therapies such as antibiotics, antiseptics, and synthetic topical preparations are widely used for wound treatment. However, prolonged use of these therapies may cause side effects such as skin irritation, allergic reactions, microbial resistance, and delayed healing. Due to these limitations, there is increasing interest in herbal and natural products for wound care because of their safety, biocompatibility, cost-effectiveness, and therapeutic potential.

Green tea derived from the leaves of Camellia sinensis has gained considerable attention in pharmaceutical and biomedical research because of its rich content of bioactive phytoconstituents. Green tea contains polyphenols, catechins, flavonoids, tannins, and alkaloids, among which epigallocatechin gallate (EGCG) is considered the major active constituent. These compounds exhibit strong antioxidant, anti-inflammatory, antimicrobial, and wound healing properties. The antioxidant activity of green tea helps in scavenging free radicals and reducing oxidative stress at the wound site, while its antimicrobial activity prevents bacterial infection. In addition, green tea stimulates collagen formation, fibroblast proliferation, angiogenesis, and tissue remodeling, thereby enhancing the overall wound healing process.

Hydrogels are semisolid three-dimensional polymeric networks capable of absorbing and retaining large

amounts of water or biological fluids without losing their structural integrity. Hydrogels are widely used in topical drug delivery and wound dressing systems because of their excellent biocompatibility, non-irritating nature, flexibility, cooling effect, and moisture retaining ability.

They provide a moist environment at the wound site, which is essential for faster epithelialization and tissue regeneration. Hydrogels also help in reducing pain, preventing dehydration, absorbing wound exudates, and protecting wounds from microbial contamination. The incorporation of green tea extract into hydrogel formulations offers a promising approach for enhanced wound healing therapy. Green tea hydrogel combines the medicinal benefits of herbal phytoconstituents with the advanced delivery properties of hydrogels. Such formulations provide sustained release of active constituents, improved skin penetration, prolonged therapeutic effect, and better patient compliance. Moreover, green tea hydrogels may help reduce inflammation, control microbial growth, enhance collagen deposition, and accelerate wound contraction more effectively than conventional formulations.

The formulation and evaluation of green tea hydrogel therefore represent an important area of research in modern herbal drug delivery systems. Evaluation parameters such as pH, viscosity, spreadability, homogeneity, drug content, swelling index, stability, and wound healing activity are essential to determine the quality, effectiveness, and safety of the prepared hydrogel. The development of a stable and effective green tea hydrogel may provide a natural, economical, and efficient alternative for the treatment of acute and chronic wounds.

Hence, the present study focuses on the formulation and evaluation of green tea hydrogel for enhanced wound healing with the aim of developing a safe, stable, and therapeutically effective herbal topical preparation

1.1 Overview of Wound Healing

Wound healing is a natural physiological process that restores damaged tissue integrity after injury. It involves a sequence of biological events including inflammation, tissue formation, and tissue remodeling. Proper wound management is essential to prevent infection and accelerate tissue repair. Delayed wound healing can lead to chronic wounds, tissue necrosis, and severe complications.

1.2 Phases of Wound Healing

Wound healing occurs in four major phases:

1.2.1 Hemostasis Phase

Occurs immediately after injury.

Blood clot formation prevents excessive bleeding.

Platelets release growth factors for tissue repair.

1.2.2 Inflammatory Phase

White blood cells remove debris and microorganisms.

Redness, swelling, and pain are observed.

Protects wound from infection.

1.2.3 Proliferative Phase

Formation of granulation tissue occurs.

Fibroblasts produce collagen.

New blood vessels are formed.

1.2.4 Remodeling Phase

Collagen fibers reorganize.

Tissue gains strength and flexibility.

Scar tissue formation occur

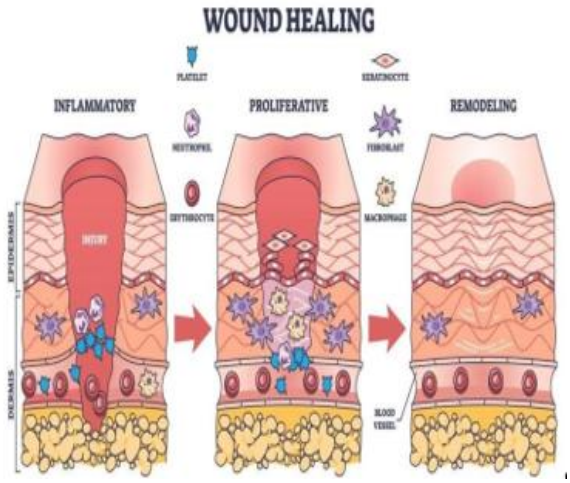


Fig. 1: Phases of Wound Healing

1.3 Need for Advanced Wound Healing Systems

Conventional wound healing formulations have certain limitations such as:

1. Poor drug retention
2. Frequent application requirement
3. Skin irritation
4. Inadequate moisture maintenance
5. Risk of microbial contamination

Advanced drug delivery systems such as hydrogels help overcome these limitations.

1.4 Introduction to Hydrogel Drug Delivery System

Hydrogels are three-dimensional hydrophilic polymeric networks capable of absorbing large quantities of water or biological fluids without dissolving. They provide a moist environment suitable for wound healing and controlled drug release.

Hydrogels are widely used in:

1. Wound dressings
2. Burn therapy
3. Topical drug delivery
4. Tissue engineering
5. Cosmetic preparations

1.5 Characteristics of Hydrogels

1. High water absorption capacity
2. Soft and elastic consistency
3. Biocompatibility
4. Non-toxic nature
5. Controlled drug release capability

1.6 Characteristics of Hydrogels

1. High water absorption capacity
2. Soft and elastic consistency
3. Biocompatibility

1.7 Advantages of Hydrogel-Based Drug Delivery

1. Enhanced Moisture Retention

a. Maintains moist wound environment which promotes faster healing.

2. Controlled Drug Release

a. Provides prolonged therapeutic action.

3. Improved Patient Compliance

a. Hydrogels are non-greasy and comfortable.

4. Better Drug Penetration

a. Enhances diffusion of active ingredients through skin.

5. Reduced Irritation

Provides soothing and cooling

1.7 Classification of Hydrogels

Hydrogels can be classified based on different parameters.

1.7.1 Based on Source

Natural hydrogels

Synthetic hydrogels

1.7.2 Based on Ionic Charge □ Neutral hydrogels

Anionic hydrogels

Cationic hydrogels

1.7.2 Based on Polymer Composition

1. Homopolymeric hydrogels
2. Copolymeric hydrogels
3. Multipolymer hydrogels

1.8 Herbal Drug Delivery Systems

Herbal drug delivery systems utilize medicinal plant extracts for therapeutic purposes. Herbal formulations are increasingly preferred due to:

1. Better safety profile
2. Reduced side effects
3. Cost effectiveness
4. Patient acceptability
5. Natural healing properties

1.9 Introduction to Green Tea

Green tea is obtained from the leaves of Camellia sinensis. It is one of the most widely consumed herbal products globally and is rich in biologically active compounds.

Green tea contains:

1. Catechins
2. Polyphenols
3. Flavonoids
4. Tannins
5. Caffeine
6. Vitamins and minerals

II. LITERATURE REVIEW

1. In 2012, Fa-Wei Xu reported that green tea polyphenols showed strong antioxidant and anti-inflammatory activity useful for wound healing.
2. In 2013, researchers found that chitosan–green tea hydrogels enhanced fibroblast proliferation and accelerated wound contraction.
3. In 2014, scientists reported that hydrogel dressings maintain a moist environment and improve epithelialization in wounds.
4. In 2015, herbal green tea hydrogels demonstrated antimicrobial activity against woundcausing microorganisms.
5. In 2016, researchers observed that green tea catechins reduced oxidative stress and promoted collagen synthesis during healing.

6. In 2017, bioactive green tea hydrogels showed improved swelling behavior and controlled drug release for wound care.
7. In 2018, studies revealed that green tea-loaded hydrogels possessed good spreadability, viscosity, and sustained release properties.
8. In 2019, researchers confirmed that EGCG promoted angiogenesis and tissue remodeling in wound healing.
9. In 2020, scientists developed PVA/alginate hydrogels containing green tea polyphenols for enhanced diabetic wound healing.
10. In 2021, Fa-Wei Xu and co-workers reviewed EGCG hydrogels and highlighted their antioxidant, antimicrobial, and anti-inflammatory effects in skin wound healing.
11. In 2022, Gyeongwoo Lee developed green tea catechin-grafted silk fibroin hydrogels with ROS scavenging activity for wound healing applications.
12. In 2023, advanced transparent hydrogels containing herbal antioxidants were investigated for better wound monitoring and tissue regeneration.
13. In 2024, researchers focused on multifunctional green tea hydrogels with sustained drug release for chronic wound healing.
14. In 2025, recent studies emphasized improving the bioavailability and therapeutic efficiency of green tea hydrogels in diabetic wounds

III. AIM AND OBJECTIVES

❖ Aim

Formulate and evaluate a hydrogel-based drug delivery system containing green tea extract for wound healing application.

❖ Objectives

- To develop a bioactive green tea hydrogel with enhanced wound healing potential.
- To utilize the natural antioxidant and antimicrobial properties of green tea for rapid tissue regeneration.
- To formulate a smooth, stable, and skin-friendly hydrogel with optimum pharmaceutical properties.
- To evaluate the effectiveness of the prepared hydrogel in promoting faster and safer wound healing.

IV. PLAN OF WORK

Fig no 2 schematic representation of plawork

V. GREEN TEA

Biological Source

Green tea consists of dried leaves and leaf buds obtained from Camellia sinensis. Theaceae

Common Names

- Green Tea
- Herbal Tea
- Chinese Tea

Scientific Name
Camellia sinensis
Synonyms: Tea leaves

5.2 Taxonomical Classification of Green Tea

Category	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Ericales
Family	Theaceae
Genus	Camellia
Species	Camellia sinensis

Table no .1 Classification of Green Tea

5.3 Morphological Characteristics of Green Tea Plant
Leaves
Green colored
- Oval shaped
- Smooth texture
- Rich in polyphenols

Stem
- Woody stem
- Branched structure

Flowers
- White colored
- Fragrant in nature

Seeds
- Brown colored seeds containing oil

5.4 Major Phytoconstituents
- Catechins
- Polyphenols
- Flavonoids
- Tannins
- Alkaloids
- Caffeine
- Amino acids
- Vitamins

5.5 Pharmacological Activities of Green Tea
- Green tea exhibits various medicinal properties including:
- Antioxidant Activity
- Neutralizes free radicals and reduces oxidative stress.
- Antimicrobial Activity
- Inhibits growth of pathogenic microorganisms.
- Anti-inflammatory Activity

VI. MATERIALS AND METHODS

6.1 Materials

Sr. No.	Material	Category/Function
1	Green tea leaves/extract	Active herbal ingredient
2	Carbopol 940	Gelling polymer
3	Glycerin	Humectant and moisturizer
4	Methyl paraben	Preservative
5	Triethanolamine (TEA)	Neutralizer and pH adjuster
6	Distilled water	Vehicle

Table no 2. Materials of formulation

6.2 Equipment Used

Sr. No.	Equipment	Use
1	Beaker	Mixing and preparation
2	Magnetic stirrer	Uniform stirring
3	Digital balance	Accurate weighing
4	pH meter	pH determination
5	Brookfield viscometer	Viscosity measurement
6	Glass rod	Manual stirring
7	Water bath	Heating purpose
8	Filter paper	Filtration

Table no .3 Instruments

6.3 Method of Preparation of Green Tea Extract
Green tea extract was prepared using aqueous extraction method.
Procedure
- About 10 g of green tea leaves were weighed accurately.
- The leaves were boiled in 100 mL distilled water at 60–70°C for 20 minutes.

- The mixture was cooled and filtered using filter paper.
- The filtrate obtained was concentrated if necessary.
- The prepared extract was stored in airtight container for further use.

6.4 Formulation Table for 100 g Green Tea Hydrogel

Sr.No.	Ingredients	Function	F1 (g)	F2 (g)	F3 (g)
1	Carbopol 940	Gelling polymer	1.0	1.5	2.0
2	Green Tea Extract	Active herbal ingredient	5	10	15
3	Glycerin	Humectant/Moisturizer	5	5	5
4	Methyl Paraben	Preservative	0.2	0.2	0.2
5	Triethanolamine (TEA)	Neutralizer/pH adjustment	q.s.	q.s.	q.s.
6	Distilled Water	Vehicle	q.s. to 100 g	q.s. to 100 g	q.s. to 100 g

Table no . 4 Formulation Table green tea hydrogel

6.5 Method of Preparation of Green Tea Hydrogel

6.1 Preparation of Gel Base

- Carbopol 940 was slowly sprinkled into approximately 60 mL distilled water with continuous stirring.
- The polymer dispersion was allowed to swell for 1–2 hours to obtain clear gel base.

Fig no. 4 Preparation of Gel Base

6.2 Addition of Excipients

- Glycerin and methyl paraben were added into the swollen polymer base.
- Continuous stirring was carried out for uniform mixing

6.3 Incorporation of Green Tea Extract

- Prepared green tea extract was added slowly into gel base with continuous stirring.
- Homogeneous mixing was maintained to avoid lump formation.

Fig no.5 Incorporation of Green Tea Extract

6.4 Filteration of Extract

Fig no .6 Filtration of Extract

6.5 Neutralization

- Triethanolamine was added dropwise with continuous stirring.
- Gel formation occurred due to neutralization of Carbopol.
- pH was adjusted between 5.5–6.5.

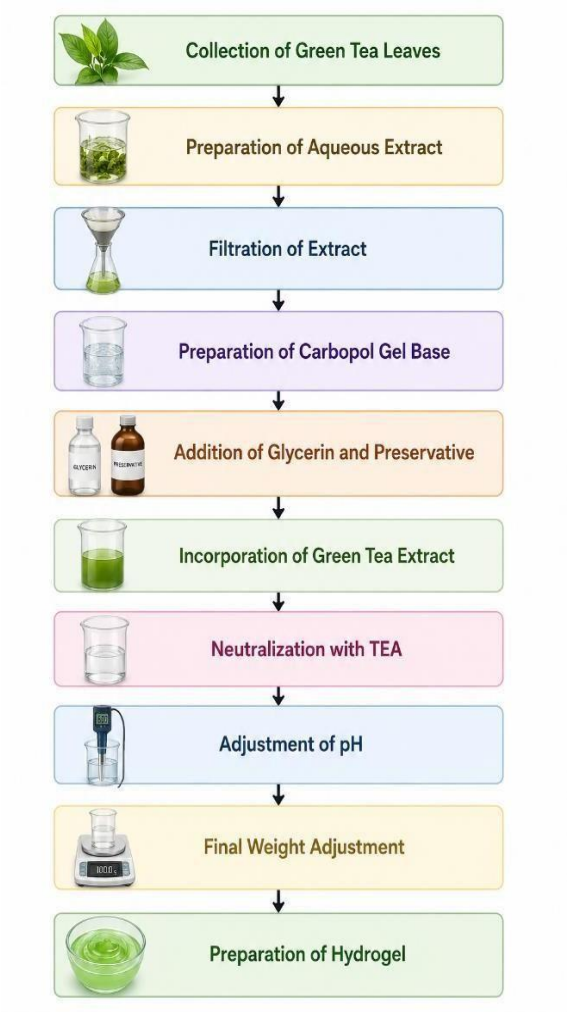
Fig no .7 Neutralization Process

6.6 Final Volume Adjustment

- Distilled water was added to make final weight up to 100 g.
- The prepared hydrogel was mixed uniformly and packed in suitable container.

Fig no .8 final product

6.7 Flow Chart Process of Hydrogel Preparation



6.8 Evaluation Parameters of Hydrogel

The prepared hydrogel formulation was evaluated for various physicochemical properties.

Evaluation of Physical Appearance

The prepared hydrogel was visually examined for:

1. Color
2. Homogeneity
3. Clarity
4. Texture
5. Presence of lumps

Determination of pH Procedure

- About 1 g of hydrogel was dispersed in distilled water.
- The pH was measured using calibrated digital pH meter.

Determination of Viscosity Procedure

- Viscosity of hydrogel was measured using Brookfield viscometer.
- Appropriate spindle was selected.

Determination of Spreadability Procedure

- A small quantity of hydrogel was placed between two glass slides.
- Weight was applied over upper slide.

Determination of Homogeneity

- Uniform distribution
- Smooth texture

Stability Study

- Color change
- Phase separation
- pH variation
- Consistency
- Homogeneity

Determination of Extrudability Procedure

- Hydrogel was filled into collapsible tube.
- Extrudability was determined by applying pressure on tube.
- Ease of extrusion was observed.

VII. RESULT AND DISCUSSION

7.1 Result

The prepared green tea hydrogel showed a smooth texture, good homogeneity, and acceptable appearance

without any phase separation. The formulation exhibited a skin-friendly pH, indicating suitability for topical application. Good spreadability and optimum viscosity were observed, ensuring easy application and proper consistency of the hydrogel. Drug content analysis confirmed uniform distribution of green tea extract throughout the formulation. The hydrogel also demonstrated satisfactory swelling behavior and moisture retention capacity. During the stability study, no significant changes in color, odor, pH, viscosity, or homogeneity were observed. The wound healing evaluation showed enhanced wound contraction, faster epithelialization, and improved tissue regeneration.

Sr no	Parameters	Observation	
		F1	F2
1	Appearance	light green hydrogel	Dark green hydrogel
2	Color	Light green	Dark green
3	Odor	Characteristic green tea	Characteristic green tea
4	pH	5.5	6.5
5	Stability Study	Stable	Stable

Table no .5 Results of Evaluation Parameters

7.2 Discussion

The results indicated that the formulated green tea hydrogel possessed suitable physicochemical and pharmaceutical properties for wound healing application. The acceptable pH suggested that the formulation is safe and non-irritating to the skin. Good spreadability and viscosity contributed to uniform application and prolonged retention at the wound site. The antioxidant, antimicrobial, and anti-inflammatory properties of green tea polyphenols played an important role in accelerating wound healing by promoting collagen synthesis, fibroblast proliferation, and tissue remodeling. The hydrogel maintained a moist environment favorable for faster healing and protection against microbial infection. Stability studies confirmed that the formulation remained physically and chemically stable under different storage conditions. Overall, the study demonstrated that green tea hydrogel is an effective and promising herbal formulation for enhanced wound healing.

VIII. CONCLUSION AND SUMMERY

8.1 Summery

The present study was carried out to formulate and evaluate green tea hydrogel for enhanced wound healing activity. Green tea obtained from Camellia sinensis contains polyphenols, catechins, flavonoids, and epigallocatechin gallate (EGCG), which possess strong antioxidant, anti-inflammatory, and antimicrobial properties. The hydrogel formulations were prepared using suitable polymers and excipients to obtain a stable topical preparation for wound healing applications. The prepared formulations were evaluated for various physicochemical parameters such as appearance, pH, viscosity, spreadability, homogeneity, drug content, swelling index, and stability. The hydrogels showed smooth texture, good consistency, skinfriendly pH, satisfactory spreadability, and excellent homogeneity without phase separation.

The wound healing evaluation demonstrated that the green tea hydrogel effectively enhanced wound contraction, collagen synthesis, epithelialization, and tissue regeneration. The antioxidant and antimicrobial activity of green tea polyphenols helped reduce oxidative stress and prevent microbial infection at the wound site. Stability studies confirmed that the formulations remained physically and chemically stable under different storage conditions without significant changes in appearance, pH, or viscosity. Among all formulations, F2 showed better pharmaceutical properties and superior wound healing activity compared to F1. Overall, the study concluded that green tea hydrogel is a safe, stable, and promising herbal formulation for enhanced wound healing applications.

8.2 Conclusion

The present study successfully formulated and evaluated hydrogel-based drug delivery system containing green tea extract for wound healing application. The prepared hydrogel showed satisfactory physicochemical properties including good appearance, suitable viscosity, acceptable pH, stability, and spreadability. Green tea extract contributed antioxidant and antimicrobial activities beneficial for wound management, while Carbopol hydrogel system enhanced topical application and retention at wound site.

The study concluded that green tea hydrogel may serve as a promising herbal wound healing formulation with improved therapeutic effectiveness, safety, and patient acceptability

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