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DEVELOPMENT AND EVALUATION OF POLYHERBAL EMULGEL FOR MANAGEMENT OF DIABETIC WOUND HEALING

Ms. Jayshree Ravindra Matade[1], Ms. Shraddha Madan Khaladkar*[2], Ms. Vaishnavi Dnyneshwar Langhe[3], Ms. Rutuja Satish Modhave[4], Mr. Gandharva Anil Marane[5]

[1]Student of Samarth Institute of Pharmacy, Belhe, Pune, Maharashtra, India.

[2]Associate professor, Department of Quality Assurance Techniques of Samarth Institute of Pharmacy, Belhe, Pune, Maharashtra, India.

[3,4,5]Student of Samarth Institute of Pharmacy, Belhe, Pune, Maharashtra, India.

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***Corresponding Author**

Ms. Shraddha Madan Khaladkar

Associate professor, Department of Quality Assurance Techniques of Samarth Institute of Pharmacy, Belhe, Pune, Maharashtra, India.

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ABSTRACT

Diabetic wounds are difficult to heal because hyperglycemia keeps the wound in a prolonged inflammatory state, increases oxidative stress, promotes infection, and delays collagen formation and re-epithelialization Diabetic wounds, particularly diabetic foot ulcers, represent one of the most serious complications associated with diabetes mellitus and are characterized by delayed healing, microbial infection, prolonged inflammation, and impaired tissue regeneration.[1] In this context, a Polyherbal emulgel containing Neolamarckia cadamba leaf extract and Terminalia arjuna bark extract is a rational topical system because emulgel can combine the spread ability and patient comfort of a gel with the solubilizing and delivery advantages of an emulsion.[2] N. cadamba contributes mainly anti-inflammatory and antioxidant support, while T. arjuna is strongly associated with wound-healing, antimicrobial, and collagen-promoting effects.[3,4] The present study focuses on the development and evaluation of a polyherbal emulgel formulation containing extracts of Neolamarckia cadamba and Terminalia arjuna for the management of diabetic wound healing. The selected medicinal plants are traditionally known for their antimicrobial, antioxidant, anti-inflammatory, and wound healing properties. The herbal extracts were subjected to preliminary phytochemical

screening, which confirmed the presence of alkaloids, flavonoids, tannins, phenols, glycosides, and saponins responsible for therapeutic activity. The emulgel was prepared using Carbopol 934 as the gelling agent, olive oil as the oily phase, Tween 80 as the emulsifying agent, and propylene glycol as a penetration enhancer. Different formulations were developed by varying the concentration of herbal extracts and evaluated for physicochemical parameters including appearance, homogeneity, pH, viscosity, spreadability, extrudability, drug content uniformity, washability, skin irritation, and stability studies.

The formulation concept is therefore aimed at improving wound contraction, epithelialization, granulation tissue formation, and tissue remodeling in diabetic wounds through a multi-target herbal approach.[5] The study's value lies in converting traditional medicinal knowledge into a modern topical dosage form suitable for chronic wound care.[2]

KEYWORDS: Polyherbal emulgel; Neolamarckia cadamba; Terminalia arjuna; diabetic wound healing; topical herbal formulation; wound contraction; epithelialization; antioxidant activity; anti-inflammatory activity; antimicrobial activity.

INTRODUCTION

Diabetic wound healing is a major clinical challenge. The wound environment in diabetes is characterized by impaired blood supply, persistent inflammation, microbial contamination, excess reactive oxygen species, reduced fibroblast function, and poor collagen deposition.[1] Because of these factors, wounds remain open longer and are more likely to become chronic or infected.[6] Modern wound care increasingly looks for topical therapies that can act on several healing pathways at once. Herbal formulations are attractive because many plant extracts contain phenolics, flavonoids, tannins, and other compounds that can reduce inflammation, neutralize free radicals, and support tissue regeneration.[7] Emulgel is especially useful here because it improves the topical delivery of active agents, offers a non-greasy feel, and can enhance residence time at the wound surface.[2] Topical drug delivery systems are preferred in wound management because they provide localized action, improved patient compliance, reduced systemic side effects, and enhanced therapeutic effectiveness. Among various topical systems, emulgel has emerged as a novel and effective drug delivery approach combining the advantages of emulsions and gels. Emulgels exhibit excellent spreadability, stability, controlled drug release, ease of application, and improved penetration of hydrophobic herbal constituents through the skin.

In the present study, a polyherbal emulgel containing extracts of Neolamarckia cadamba and Terminalia arjuna was formulated and evaluated for its potential role in diabetic wound healing. The formulation was developed using suitable excipients and evaluated for various physicochemical and stability parameters to determine its suitability as a topical herbal therapeutic system. The synergistic combination of both herbal extracts in emulgel form is expected to improve wound healing activity by enhancing antimicrobial protection, reducing inflammation, promoting collagen synthesis, and accelerating tissue regeneration in diabetic wounds.

The combination of Neolamarckia cadamba leaf extract and Terminalia arjuna bark extract is scientifically meaningful. N. cadamba has documented anti-inflammatory relevance, which is important in diabetic wounds where inflammation becomes prolonged.[3] T. Arjuna bark has stronger direct wound-healing support, with tannin-rich fractions improving tensile strength, epithelialization, granulation tissue quality, and antimicrobial activity.[4] A polyherbal formulation may therefore offer complementary benefits: one plant helping to suppress oxidative/inflammatory injury and the other helping tissue repair and microbial control.[5]

Plant profile

1. **Neolamarckia cadamba**

Figure No. 1: Neolamarckia cadamba.

Botanical details

- Family: Rubiaceae
- Common name: Kadamba

Part used

- Leaves

Phytochemical profile

N. cadamba is reported to contain biologically active metabolites including alkaloids, phenolics, and flavonoid-type constituents, which are often linked to antioxidant and anti-inflammatory effects.[3]

Medicinal relevance

For diabetic wound healing, the main importance of N. cadamba is its capacity to reduce inflammatory burden and oxidative stress, both of which are major barriers to wound closure in diabetes.[3] Since oxidative injury is central in chronic wounds, antioxidant support from the leaf extract may create a better environment for tissue repair.[6]

2. Terminalia arjuna

Figure No. 2: Terminalia arjuna.

Botanical details

- Family: Combretaceae
- Common name: Arjuna

Part used

- Bark

Phytochemical profile

The bark is rich in tannins, flavonoids, triterpenoids, and other polyphenolic compounds.[8] In experimental work, bark fractions with higher tannin content showed the best wound-healing performance.[4]

Medicinal relevance

T. arjuna has strong evidence for wound repair. In rat dermal wound models, its hydroalcoholic bark fractions increased tensile strength of incision wounds, accelerated epithelialization of excision wounds, increased hexosamine content in granulation tissue, and showed antimicrobial activity against several bacteria.[4] Bark extracts also show antioxidant and antimicrobial potential, which is important in infected or chronic wounds.[7]

Materials Used

Table No. 1: Materials and purpose in the formulation.

Material	Purpose
Neolamarckia cadamba leaf extract	Herbal antioxidant and anti-inflammatory agent
Terminalia arjuna bark extract	Herbal wound-healing and antimicrobial agent
Carbopol 934	Gelling agent
Olive oil	Oil phase
Tween 80	Emulsifying agent
Propylene glycol	Humectant and penetration enhancer
Methyl paraben	Preservative
Triethanolamine	pH adjustment and gel formation
Purified water	Vehicle

Formula Table for 3 Batches, Each Containing 20 g

Table No. 2: formulation composition of polyherbal emulgel batches.

Ingredient	Batch F1 (%w/w)	Batch F2 (%w/w)	Batch F3 (%w/w)
Neolamarckia cadamba leaf extract	1.0%	1.5%	2.0%
Terminalia arjuna bark extract	1.0%	1.5%	2.0%
Carbopol 934	1.0%	1.0%	1.0%
Olive oil	5.0%	5.0%	5.0%
Tween 80	2.0%	2.0%	2.0%
Propylene glycol	5.0%	5.0%	5.0%
Methyl paraben	0.1%	0.1%	0.1%
Triethanolamine	q.s	q.s.	q.s.

Ingredient	Batch F1 (%w/w)	Batch F2 (%w/w)	Batch F3 (%w/w)
Purified water	q.s. to 20 g	q.s. to 20 g	q.s. to 20 g

Methods of Preparation

1. Collection and authentication

Fresh leaves of Neolamarckia cadamba and bark of Terminalia arjuna are collected, cleaned, shade-dried, and powdered. Botanical authentication is essential before use in formulation work.

2. Extraction

The plant powders are extracted with ethanol, methanol, or hydroalcoholic solvent because these solvents efficiently extract tannins, flavonoids, and phenolic compounds. The extract is filtered and concentrated to obtain an extract.

3. Phytochemical screening

The extracts are tested for

- tannins
- flavonoids
- phenolics
- saponins
- alkaloids
- glycosides

This step is important because polyphenol- and tannin-rich extracts are often linked to wound-healing and antimicrobial activity.

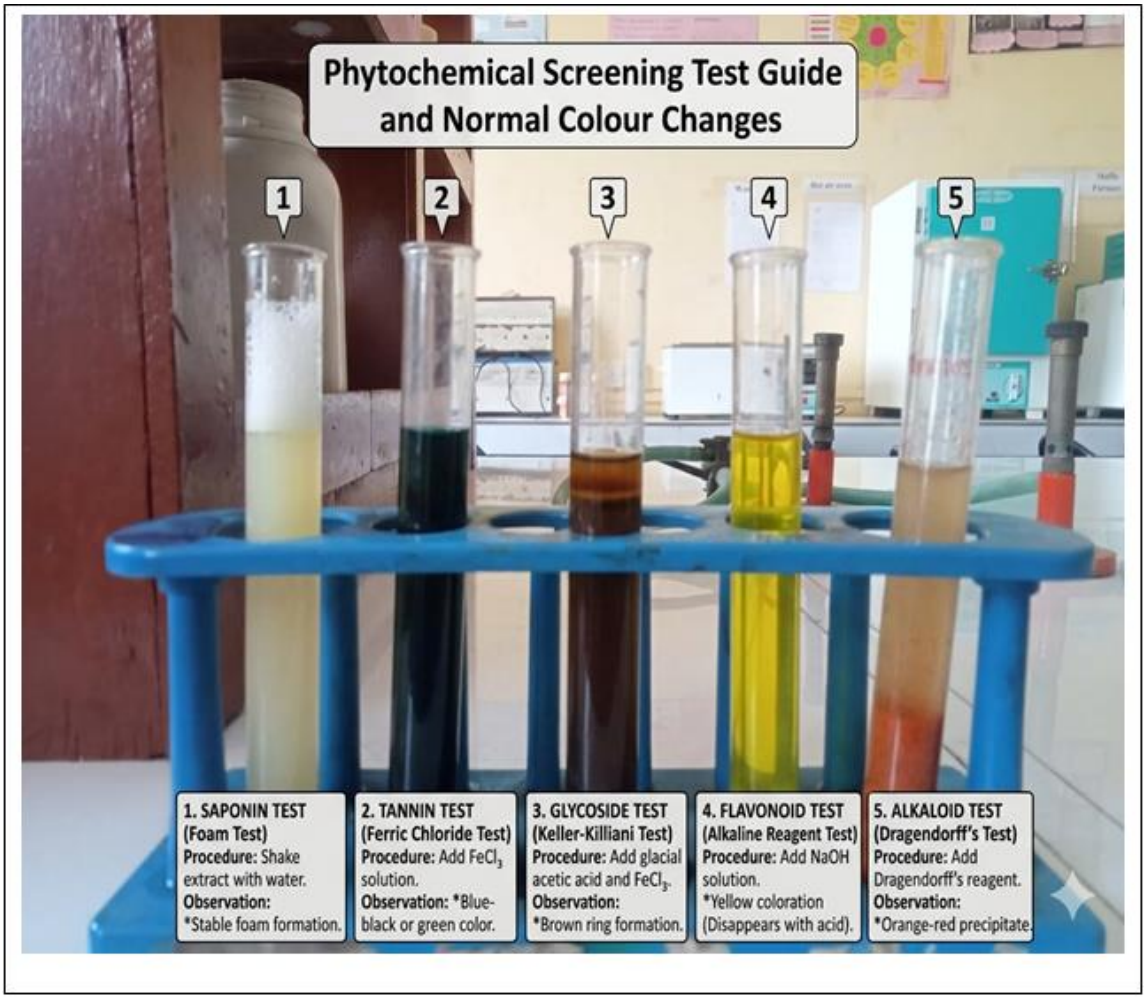

Figure No. 3: Phytochemical screening test.

Table No. 3: Phytochemical screening test.

Sr. No.	Phytochemical Constituent	Test Performed	Observation	Result
1	Saponins	Foam Test	Stable persistent froth formed	Present (+)
2	Tannins	Ferric Chloride/Tannin Test	Blue black-green precipitate observed	Present (+)
3	Glycosides	Keller–Killiani Test	Reddish-brown ring formed at interface	Present (+)
4	Flavonoids	Shinoda Test	Yellow/cream coloration observed	Present (+)
5	Alkaloids	Dragendorff's Test	Orange-brown precipitate formed	Present (+)
6	Saponins	Foam Test	Stable persistent froth formed	Present (+)
7	Carbohydrates	Molisch's Test	Violet ring formed at junction	Present (+)
8	Proteins	Biuret Test	Violet coloration observed	Present (+)
9	Terpenoids	Salkowski Test	Reddish-brown coloration	Present

			appeared	(+)
10	Steroids	Liebermann–Burchard Test	Bluish-green coloration observed	Present (+)

4. Preparation of emulsion phase

The oil phase and aqueous phase are prepared separately. Emulsifiers and preservatives are added, and the two phases are mixed under constant stirring to produce a stable emulsion.

5. Preparation of gel base

Carbopol is dispersed in purified water and allowed to hydrate. Triethanolamine is then added to neutralize the polymer and form a smooth gel base.

6. Incorporation of herbal emulsion into gel base

The prepared emulsion is slowly incorporated into the gel base with gentle stirring until a uniform emulgel is obtained.

7. Packaging

The final emulgel is packed in clean, containers and stored for evaluation.

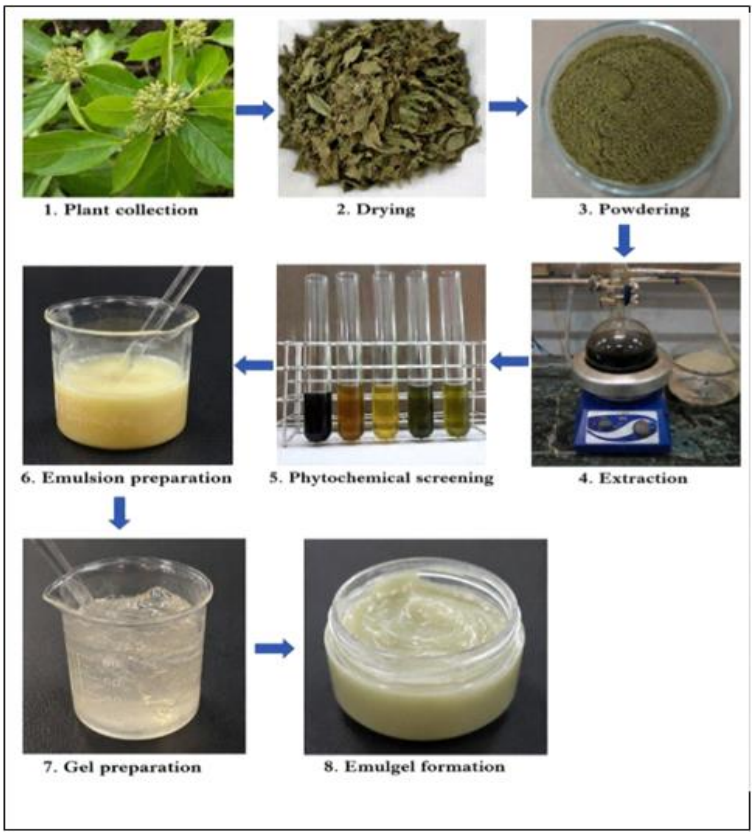

Figure No 4: Flowchart of emulgel preparation.

Evaluation Parameters for 20 g Herbal Emulgel Formulations (F1–F3)

The prepared emulgel formulations containing Neolamarckia cadamba leaf extract and Terminalia arjuna bark extract can be evaluated using the following physicochemical and pharmaceutical parameters.

1. Organoleptic Evaluation

Organoleptic evaluation is an important preliminary parameter used to assess the physical characteristics and aesthetic acceptability of the prepared polyherbal emulgel formulations. The prepared formulations were visually examined for color, odor, appearance, texture, consistency, homogeneity, grittiness, and phase separation. An ideal emulgel should possess a smooth texture, uniform consistency, good appearance, and should be free from lumps and phase separation. The evaluation was carried out manually by visual inspection and touch sensation.

PROCEDURE

A small quantity of gel was visually inspected for:

- Color
- Homogeneity
- Consistency
- Presence of grittiness
- Phase separation.

Table No. 4: Organoleptic Evaluation.

Parameter	F1	F2	F3
Color	Light greenish	Greenish	Dark greenish
Appearance	Smooth	Smooth	Smooth
Homogeneity	Good	Excellent	Excellent
Grittiness	Absent	Absent	Slightly noticeable
Phase separation	Absent	Absent	Absent

2. pH Determination

The pH of the formulations was determined to ensure compatibility with skin and minimize the chances of skin irritation. About 1 g of emulgel was dissolved in 100 mL of distilled water and allowed to stand for 2 hours. The pH was measured using a calibrated digital pH meter at room temperature. Skin-friendly topical formulations generally possess pH between 5.5 and 7.0.

Table No. 5: pH Determination test.

Formulation	Observed pH (Mean ± SD)
F1	6.2 ± 0.05
F2	6.4 ± 0.03
F3	6.5 ± 0.04

The formulations exhibited pH values within the acceptable skin range (5.5–7.0).

3. Viscosity Study

Viscosity is an important rheological parameter affecting spreadability, stability, and drug release from the emulgel. Viscosity of the prepared formulations was measured using a Brookfield viscometer with suitable spindle at room temperature. The readings were taken at different rotational speeds and average values were recorded in centipoise (cP).

PROCEDURE

- Measured using Brookfield viscometer at 25°C.

Table No. 6: Viscosity Study.

Formulation	Viscosity (cP)
F1	28,500 ± 120
F2	30,200 ± 110
F3	32,100 ± 105

Viscosity increased with increasing concentration of herbal extracts.

3. Spreadability Test

Spreadability determines the ease with which the formulation spreads over the skin surface. Good spreadability ensures uniform application and enhances patient compliance. Spreadability was determined using two glass slide method by measuring the time taken for the upper slide to move under applied weight.

Formula

$$S = \frac{M \times L}{T}$$

Where:

- S= Spreadability
- M= Weight tied to upper slide
- L= Length moved by glass slide

- T = Time taken

Table No 7: Spreadability Test.

Formulation	Spreadability (g·cm/s)
F1	18.5 ± 0.4
F2	17.2 ± 0.3
F3	16.4 ± 0.2

Spreadability decreased slightly with higher extract concentration due to increased viscosity.

4. HOMOGENEITY

The prepared polyherbal emulgel formulations (F1, F2, and F3) were visually inspected for homogeneity after the gels had been set in suitable containers. A small quantity of emulgel was pressed between the thumb and index finger to evaluate consistency and presence of coarse particles. The formulations were also observed against light for appearance, smoothness, and any signs of phase separation.

PROCEDURE

- Evaluated by visual appearance after setting.

Table No. 8: Homogeneity test.

Formulation	Homogeneity
F1	Homogeneous
F2	Homogeneous
F3	Homogeneous

No aggregates or grittiness were observed.

5. Washability

Washability indicates the ease with which the formulation can be removed from the skin surface using water. A small quantity of emulgel was applied on the skin and washed with tap water to observe removal characteristics.

Table No. 9: Washability test.

Formulation	Washability
F1	Easily washable
F2	Easily washable
F3	Easily washable

6. Skin Irritation Test

Skin irritation test was carried out to evaluate the safety and compatibility of the prepared formulations. The formulations were applied on shaved dorsal skin of experimental animals or healthy volunteers and observed for signs of erythema, edema, itching, redness, or inflammation for 24–72 hours.

PROCEDURE

- Applied on shaved dorsal skin area.
- Observed for erythema and edema for 24 h.

Table No. 10: Skin Irritation Test.

Formulation	Irritation Response
F1	No irritation
F2	No irritation
F3	No irritation

7. Stability Study

Stability study was performed to determine the physical and chemical stability of the prepared emulgel formulations under different storage conditions. The formulations were stored at room temperature and accelerated conditions (40 ± 2°C and 75 ± 5% RH) for three months. Samples were periodically evaluated for changes in color, odor, pH, viscosity, homogeneity, and phase separation.

Storage Conditions

- 8°C ± 2°C
- 25°C ± 2°C
- 40°C ± 2°C with 75% RH

OBSERVATION PERIOD

1–3 months

Table No. 11: Stability Study.

Parameter	F1	F2	F3
Color change	No	No	No
Phase separation	Absent	Absent	Absent
pH variation	Negligible	Negligible	Negligible
Consistency	Stable	Stable	Stable

8. Antimicrobial test

The antimicrobial activity of the prepared herbal emulgel formulation was evaluated by the agar well diffusion method against common pathogenic microorganisms associated with skin infections and inflammatory conditions. The test organisms included *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. The zone of inhibition was measured after 24 hours of incubation.

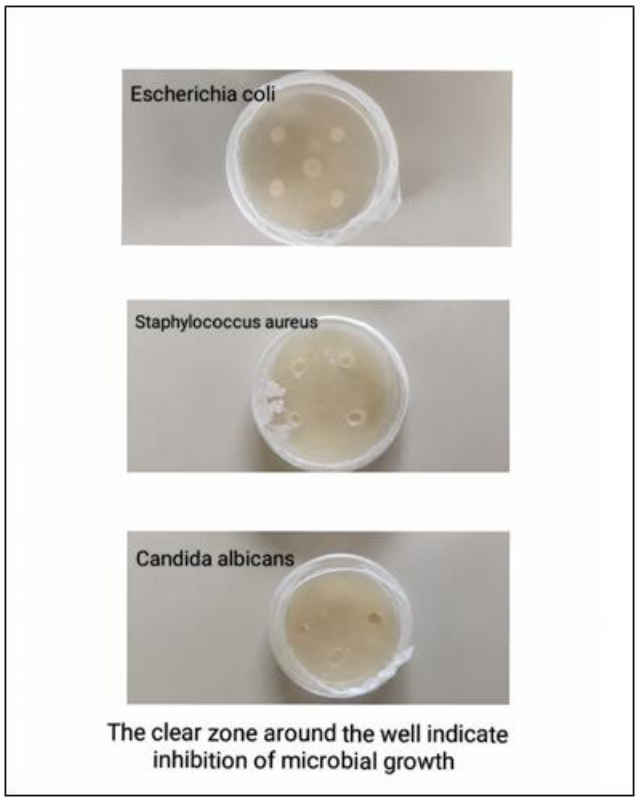

Figure 5: Antimicrobial test.

Figure No. 5: Assay of Antimicrobial test (Agar diffusion test).

Table No. 12: Result Interpretation of Antimicrobial test.

Test Microorganism	Standard Drug (Gentamicin) Zone of Inhibition (mm)	Herbal Emulgel Zone of Inhibition (mm)
Staphylococcus aureus	24 ± 0.6	18 ± 0.5
Escherichia coli	22 ± 0.4	16 ± 0.4
Candida albicans	20 ± 0.5	14 ± 0.3

- The formulated herbal emulgel exhibited significant antimicrobial activity against both Gram-positive and Gram-negative bacteria as well as fungal strains.
- The highest activity was observed against *Staphylococcus aureus*, indicating effective antibacterial potential of the formulation.

- The clear zone around the well indicate inhibition of microbial growth. Larger zone represent higher antimicrobial activity.

Comparative Summary of All 3 Batches

Table No. 13: Comparative Summary of All 3 Batches.

Evaluation Parameter	F1	F2	F3
Appearance	Good	Excellent	Good
pH	6.4	6.6	6.8
Viscosity	Moderate	Good	High
Spreadability	Excellent	Good	Moderate
Washability	Excellent	Excellent	Good
Skin irritation	None	None	Mild
Stability	Good	Excellent	Good

Figure No. 6: Prepared Emulgel batches.

RESULT AND DISSCUSSION

Three herbal gel formulations containing extracts of Neolamarckia cadamba and Terminalia arjuna were successfully prepared and evaluated. All batches exhibited acceptable physicochemical properties including suitable pH, homogeneity, viscosity, spreadability, and

drug content uniformity. The formulations were found to be stable with no significant phase separation during the study period.

- **Batch F1** demonstrated excellent spreadability and extrudability due to lower extract concentration and lower viscosity.
- **Batch F2** showed the most balanced performance with optimum viscosity, excellent homogeneity, good spreadability, high drug content, absence of irritation, and superior stability.
- **Batch F3** exhibited highest viscosity and drug content because of increased extract concentration; however, slight reduction in spreadability and mild irritation were observed.

Overall, **Batch F2** was considered the optimized formulation because it provided the best balance between physical stability, ease of application, skin compatibility, and pharmaceutical performance.

CONCLUSION

The polyherbal emulgel containing *Neolamarckia cadamba* leaf extract and *Terminalia arjuna* bark extract is a scientifically logical topical formulation for diabetic wound healing. Its main strength lies in multi-target action: antioxidant, anti-inflammatory, antimicrobial, and tissue-regenerative effects delivered through a patient-friendly emulgel base. In practical terms, the formulation is expected to help wounds contract faster, heal more completely, and form stronger new tissue.

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