International Journal of Medicine and Pharmaceutical Research
E-ISSN: 2321-2624 | https://doi.org/10.30904/j.ijmpr.2026.5050

Formulation and Evaluation of Polyherbal Gel Comprising Rubia Cordifolia, Acalypha Indica and Musa Paradisiaca for Diabetic Wound Healing

N. Deepa*, M. Narmatha, P. Narmatha, M. Neevatha

Faculty of Pharmacy, Sree Balaji Medical College and Hospital Campus, Bharath Institute of Higher Education and Research (BIHER), Chromepet, Chennai - 600044, Tamil Nadu, India.

***Corresponding E-Mail:** deepanatarajan@yahoo.com*

Received: 30-04-2026 | Revised: 31-05-2026 | Accepted: 25-06-2026 | Published: 24-07-2026

ABSTRACT
Delayed cutaneous repair remains a major complication of diabetes mellitus, driven by chronic hyperglycaemia, oxidative stress and impaired angiogenesis. The present study was undertaken to formulate and evaluate a topical polyherbal gel incorporating aqueous extracts of Rubia cordifolia (root), Musa paradisiaca (fruit peel) and Acalypha indica (leaf) for diabetic wound management. Authenticated plant powders were extracted by cold maceration, screened for phytoconstituents, and incorporated into a Carbopol 940-based hydrogel base to yield five formulations (F1-F5). The gels were evaluated for organoleptic properties, pH, viscosity, spreadability, extrudability and drug content, and were characterized by FTIR and UV-Visible spectroscopy; antioxidant activity was assessed by the DPPH assay. Phytochemical screening confirmed the presence of flavonoids, tannins, alkaloids, glycosides and triterpenoids. FTIR spectra showed characteristic O-H, C=O, C=C and C-O-C absorptions, and the gel exhibited UV absorption maxima at 271, 315 and 428 nm corresponding to combined phenolic, flavonoid and anthraquinone chromophores. Formulation F3 showed the most favourable pH (6.52), viscosity (38,600 cP), spreadability (18.8 g.cm/s) and drug content (98.8%), together with the strongest antioxidant activity (IC50 = 21.3 microg/mL), comparable to ascorbic acid (IC50 = 15.8 microg/mL). The optimised gel remained stable over three months of accelerated storage. These findings indicate that the developed polyherbal gel possesses suitable physicochemical characteristics and pronounced antioxidant activity, supporting its further evaluation as a topical candidate for diabetic wound healing.
Keywords: Diabetic wound healing, Polyherbal gel, Rubia cordifolia, Musa paradisiaca, Acalypha indica, DPPH assay

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterised by sustained hyperglycaemia resulting from defective insulin secretion, impaired insulin action, or both [1]. Global prevalence estimates have risen sharply since the projections of Wild et al., who anticipated an increase from 171 million affected individuals in 2000 to 366 million by 2030 [2]; contemporary figures from the International Diabetes Federation now exceed 537 million cases, underscoring the scale of the disease burden [3].

Among the complications of diabetes, impaired cutaneous wound healing is particularly consequential, predisposing patients to chronic ulceration and, in severe cases, lower-limb amputation. Boulton et al. reported that foot ulceration precedes approximately 85% of diabetes-related amputations, emphasising the need for effective wound-care strategies [4].

The pathophysiological basis of delayed healing in diabetic tissue is multifactorial and includes microvascular insufficiency, peripheral neuropathy, heightened susceptibility to infection, and derangement of the normal haemostasis-inflammation-proliferation-remodelling sequence 5. Chronic hyperglycaemia promotes the formation of advanced glycation end-products, elevates matrix metalloproteinase activity and increases reactive oxygen species (ROS) generation, collectively impairing keratinocyte migration, fibroblast proliferation, collagen deposition and neovascularisation 6,7. Xu et al. demonstrated that excessive ROS accumulation in wound-edge keratinocytes disrupts Nrf2-mediated antioxidant signalling in a streptozotocin-induced diabetic murine model, providing a mechanistic rationale for the incorporation of antioxidant-rich agents into wound-healing formulations [7].

Contemporary management of diabetic wounds relies on glycaemic control, surgical debridement, infection control, pressure off-loading, vascular intervention and advanced dressings, including hydrocolloids, hydrogels, alginates and growth-factor-based products such as becaplermin [8]. While effective, many of these interventions are costly, and some synthetic agents carry a risk of local irritation. This has sustained interest in medicinal plants as sources of wound-healing agents, motivated by their traditional use, comparatively low cost, and demonstrated antimicrobial, anti-inflammatory and antioxidant activities [9]. Three medicinal plants were selected for the present study based on their documented wound-healing potential. Rubia cordifolia Linn. (Rubiaceae), known as Manjistha, is a well-recognised Ayurvedic herb whose root contains anthraquinone derivatives such as purpurin and alizarin, reported to possess antioxidant, anti-inflammatory and antibacterial properties 10-13. Singh and Ali demonstrated that

topical application of a methanolic root-extract ointment significantly enhanced wound contraction and hydroxyproline content in excision, incision and dead-space wound models [11]. Acalypha indica Linn. (Euphorbiaceae), commonly termed Indian nettle or Kuppaimeni, has traditionally been used for skin infections and possesses documented antibacterial activity against common wound pathogens, including Staphylococcus aureus and Pseudomonas aeruginosa [14,15]. Abirami et al. reported accelerated wound closure and elevated hydroxyproline content following topical application of an aqueous leaf-extract gel in streptozotocin-induced diabetic rats [16]. Musa paradisiaca Linn. (Musaceae), the banana plant, yields peel and leaf extracts rich in flavonoids, tannins and phenolic compounds, associated with accelerated wound contraction, antimicrobial activity and cytoprotective effects on fibroblast cultures [17-19]. Given the complementary phytochemical profiles of these three plants, the present study hypothesised that a combined polyherbal extract would exert a more pronounced antioxidant and wound-healing effect than any single constituent extract, consistent with the concept of pharmacological synergism widely invoked in polyherbal formulation design [20]. This investigation was therefore undertaken to formulate a topical hydrogel incorporating aqueous extracts of R. cordifolia, M. paradisiaca and A. indica, and to characterize the resulting formulation with respect to its physicochemical properties, spectroscopic profile and in vitro antioxidant activity.

Materials and Methods

Collection and authentication of plant material: Fresh roots of Rubia cordifolia, unripe fruit peel of Musa paradisiaca, and the whole plant of Acalypha indica were procured from authenticated local sources in and around Chennai, Tamil Nadu, during the year 2026. The collected materials were washed thoroughly under running tap water followed by distilled water, and shade-dried at ambient temperature (25-30°C) until a constant weight was attained. The dried materials were pulverised separately into coarse powder, sieved for uniform particle size, and stored in airtight containers protected from light and moisture. Botanical identity was authenticated by Dr D. Aravind, Department of Medicinal Botany, National Institute of Siddha (Ministry of AYUSH, Government of India), Chennai (Certificate No. NISMB9352026); voucher specimens were deposited in the departmental herbarium.

Extraction of plant material: Extraction was performed by cold maceration. Two grams of each powdered plant material were separately macerated in distilled water at a ratio of 1:10 (w/v) for 72 hours at room temperature, with intermittent shaking two to three times daily. Each macerate was filtered through muslin cloth followed by Whatman No. 1 filter paper, and the marc was re-extracted twice with fresh solvent. The pooled filtrates were concentrated under reduced pressure in a rotary evaporator (40-45°C) and dried in a hot-air oven (40°C) until a semisolid residue was obtained. Percentage yield was calculated as the ratio of dried extract weight to initial powdered drug weight, multiplied by 100. The dried extracts were stored in amber, airtight containers at 4°C.

Preliminary phytochemical screening: The pooled polyherbal extract was subjected to standard qualitative tests to detect alkaloids (Dragendorff's test), flavonoids (alkaline reagent test), glycosides (ammonia test), tannins (lead acetate test), saponins (froth test), triterpenoids (Salkowski test), carbohydrates (Molisch's test), proteins (Biuret test), steroids (Liebermann-Burchard test), and anthraquinones (Borntrager's test), following established pharmacognostic protocols [21,22].

Preparation of gel base and polyherbal gel: The gel base was formulated using Carbopol 940 as gelling agent, hydroxypropyl methylcellulose (HPMC) as co-polymer, methylparaben as preservative, and propylene glycol as humectant, with triethanolamine for pH neutralisation. Carbopol 940 was dispersed in about 60% of the total purified water under continuous mechanical stirring (500 rpm) and hydrated for 12 hours. Triethanolamine was added dropwise until a clear, transparent gel of pH ~6.5 was obtained. Methylparaben was dissolved in warmed (60°C) propylene glycol to form the preservative solution. The three plant extracts were combined in equal proportion and dissolved in the remaining water with gentle warming (40°C). The preservative solution and combined extract solution were incorporated into the Carbopol gel base with uniform mixing, and the weight adjusted to 100 g with purified water. Five formulations (F1-F5) were prepared by varying the Carbopol 940 concentration while keeping the herbal extract load constant, to identify the composition offering the optimal balance of rheological and drug-release properties. The composition of the optimised formulation is shown in Table 1.

Table 1: Composition of the Optimized Polyherbal Gel Formulation (Per 100g)

Ingredient	Quantity
Combined herbal extract (1:1:1)	6 g
Carbopol 940	1 g
HPMC	2 g
Methylparaben	0.20 g
Propylene glycol	10 mL
Triethanolamine	q.s. (to pH 6.5)
Distilled water	q.s. to 100 g

Evaluation of the formulated gel: All five batches were evaluated for organoleptic properties (colour, odour, texture, feel); pH (1 g of gel in 100 mL distilled water, digital pH meter, triplicate, 25 ± 2°C); viscosity (Brookfield viscometer, spindle no. 64, 20 rpm, triplicate); spreadability (parallel-plate method, S = M x L/T, where M is applied mass, L the distance moved and T the time taken); extrudability (1 kg load applied for 10 seconds to a filled collapsible tube); and drug content uniformity (UV-Visible spectrophotometry at the pre-determined lambda-max against a calibration curve, triplicate). In vitro drug release was studied using a Franz diffusion cell with phosphate buffer (pH 7.4) as receptor medium at 37 ± 0.5°C, with samples withdrawn fixed intervals and analyzed spectrophotometrically. The optimized formulation was further subjected to accelerated stability testing at 40 ± 2°C/75 ± 5% relative humidity for three months as per ICH Q1A(R2) guidelines 23. FTIR spectroscopic analysis: Dried extracts were finely powdered and blended with IR-grade potassium bromide (KBr) at 1:100 (w/w) and compressed into pellets. Spectra were recorded over 4000-400 cm-1 at a resolution of 4 cm-1, using pure KBr as reference blank. UV-Visible spectral analysis: A 100 mg portion of the gel was dissolved in 100 mL ethanol, sonicated for 10-15 minutes, and filtered. The filtrate was scanned between 200 and 800 nm

against an ethanol blank, and the absorption maxima (lambda-max) compared with those of the individual extracts. In vitro antioxidant activity (DPPH assay): The DPPH free-radical scavenging assay was carried out following the principle described by Blois and standardised by Brand-Williams et al. 24,25. A 0.1 mM DPPH stock solution was prepared in methanol. Test samples (individual extracts and combined extract incorporated in gels F1-F5) and ascorbic acid standard were prepared at 1 mg/mL and serially diluted to 10, 20, 40, 80, 100 and 200 microg/mL. In a 96-well microplate, 100 microL of each test concentration was combined with 100 microL of 0.1 mM DPPH solution, incubated in the dark for 30 minutes, and absorbance measured at 517 nm. Percentage radical-scavenging activity was calculated as [(Ac - At)/Ac] x 100, and IC50 values derived from linear regression of scavenging activity against concentration. All determinations were performed in triplicate.

Results

Organoleptic characteristics: The formulated polyherbal gel was transparent, possessed a characteristic mild herbal odour, and exhibited a smooth, homogeneous texture with a soft, non-greasy, easily spreadable feel, indicating suitability for topical application (Table 2).

Table 2: Organoleptic Characteristics of the Formulated Polyherbal Gel

Parameter	Observation
Colour	Transparent
Odour	Characteristic herbal odour
Texture	Smooth and homogeneous
Feel	Soft, non-greasy, easily spreadable

Preliminary phytochemical screening:

Qualitative screening of the combined polyherbal extract confirmed the presence of alkaloids, flavonoids, glycosides, tannins, saponins and triterpenoids, while carbohydrates, proteins, steroids and free anthraquinones were not detected (Table 3). Flavonoids and triterpenoids gave the most pronounced reactions, consistent with the phenolic- and terpenoids rich profiles previously reported for R. cordifolia, A. indica and M. paradisiaca [10,14,17].

Table 3: Preliminary Phytochemical Screening of the Combined Polyherbal Extract

Phytoconstituent	Test	Observation	Result
Alkaloids	Dragendorff's test	Reddish orange precipitate	++
Flavonoids	Alkaline reagent test	Dark yellow colouration	+++
Glycosides	Ammonia test	Red/pink colour in ammoniacal layer	++
Tannins	Lead acetate test	White precipitate	++
Saponins	Froth test	Persistent foam	++
Triterpenoids	Salkowski test	Reddish-brown interface	+++
Carbohydrates	Molisch's test	No violet ring	-
Proteins	Biuret test	No violet colour	-
Steroids	Liebermann-Burchard test	No blue-green colour	-
Anthraquinones	Borntrager's test	No pink/red colour	-

(+++) strongly present; (++) moderately present; (+) slightly present; (-) absent.

FTIR spectroscopic characterisation: The FTIR spectrum of the polyherbal gel displayed ten principal absorption bands (Table 4), including a broad O-H stretch at 3398 cm-1 indicative of phenolic and alcoholic hydroxyl groups, a C-H stretch at 2926 cm-1, a carbonyl (C=O) stretch at 1722 cm-1 consistent with carboxylic acid/ester/ketone functionalities, olefinic C=C stretching at 1645 cm-1, aromatic ring vibrations at 1604 cm-1, and C-O/C-O-C stretching bands at 1246 and 1058 cm-1 attributable to ethers, esters and phenolic linkages. No unassigned or anomalous peaks were observed relative to the spectra of the individual extracts, suggesting the absence of significant chemical interaction between the herbal constituents and the excipients of the gel base.

Table 4: FTIR absorption bands and functional group assignments

Wavenumber (cm-1)	Range (cm^{-1})	Functional group assignment
3398	3500-3200	O-H stretch (alcohols, phenols)
2926	3000-2850	C-H stretch (alkanes)
1722	1750-1700	C=O stretch (carbonyl/carboxylic acid/ester/ketone)
1645	1620-1605	C=C stretch (alkenes)
1604	1610-1580	Aromatic C=C stretch
1512	1520-1500	N-O asymmetric stretch (nitro compounds)
1372	1380-1360	C-H bending (alkanes)
1246	1260-1230	C-O stretch (esters, ethers, phenols)
1058	1060-1030	C-O-C stretch (ethers, phenols)
812	850-800	C-H out-of-plane bending (aromatics)

UV-Visible spectral analysis: UV-Visible scanning revealed distinct absorption maxima for each individual extract and the formulated gel (Table 5). Rubia cordifolia exhibited peaks at 259 and 289 nm, characteristic of aromatic phenolic chromophores, together with a band at 437 nm attributable to anthraquinone derivatives such as purpurin and alizarin. Musa paradisiaca and Acalypha indica displayed absorption maxima in the 268-335 nm range, consistent with phenolic and flavonoid chromophores. The formulated gel exhibited three absorption maxima at 271, 315 and 428 nm, reflecting the combined phenolic, flavonoid and anthraquinone constituents of the three plant extracts, confirming successful incorporation of the bioactive compounds without loss of spectral integrity or optical clarity.

Table 5: UV-Visible Absorption Maxima of Individual Extracts and the Polyherbal Gel

Sample	Peak 1 (nm)	Peak 2 (nm)	Peak 3 (nm)	Probable chromophore
Rubia cordifolia	259	289	437	Phenolic and anthraquinone
Musa paradisiaca	272	335	-	Phenolics and flavonoids
Acalypha indica	268	310	-	Phenolics and flavonoids
Polyherbal gel	271	315	428	Combined phenolic, flavonoid, anthraquinone

In vitro antioxidant (DPPH) activity:

The DPPH radical-scavenging capacity varied across the five gel formulations, with IC50 values ranging from 21.3 to 52.6

microg/mL (Table 6). Formulation F3 exhibited the strongest antioxidant activity (IC50 = 21.3 microg/mL), followed by F5 (28.3 microg/mL); both approached the potency of the ascorbic acid reference standard (IC50 = 15.8 microg/mL). Formulations F1, F2 and F4 displayed moderate antioxidant activity, with IC50 values of 38.4, 52.6 and 44.7 microg/mL, respectively.

Physicochemical evaluation of formulated gels:

All five formulations were clear, transparent and homogeneous, with no phase separation, and remained stable under the storage conditions employed (Table 7). pH values ranged from 6.27 to 6.52, compatible with topical application. Viscosity increased progressively with increasing Carbopol 940 concentration, from 12,400 cP (F1) to 52,400 cP (F5), while spreadability decreased correspondingly from 32.4 to 9.4 g.cm/s. Extrudability increased with increasing viscosity, from 18.4 g/cm2 (F1) to 38.6 g/cm2 (F5). Drug content ranged from 96.4% to 98.8% across all batches. Formulation F3 demonstrated the most favourable overall balance of viscosity (38,600 cP) and spreadability (18.8 g.cm/s), together with the highest drug content (98.8%), and was selected as the optimized formulation. Over three months of accelerated stability testing, no significant change in appearance, pH, viscosity, spreadability or drug content was observed. The optimized formulation additionally exhibited a cumulative in vitro drug release of 79.2% over 8 hours, indicating a sustained release profile.

Discussion

The present findings collectively support the pharmaceutical feasibility and biological relevance of a polyherbal hydrogel combining Rubia cordifolia, Acalypha indica and Musa paradisiaca for diabetic wound management. Phytochemical screening confirmed the presence of flavonoids, tannins, alkaloids, glycosides and triterpenoids, all of which have been individually implicated in wound-repair mechanisms through antioxidant, antimicrobial and anti-inflammatory pathways 9,26. This profile is consistent with earlier phytochemical investigations of R. cordifolia root, which have similarly reported carbohydrates, alkaloids, saponins, glycosides, phenolics and tannins as major constituents underlying its traditional use for blood purification and dermatological conditions [13,27].

The FTIR spectrum of the formulated gel showed no unexpected shifts or additional peaks relative to those anticipated from the constituent extracts, indicating that the herbal actives were physicochemically compatible with the Carbopol-based gel matrix. The prominent O-H and C=O bands are consistent with the phenolic and carbonyl-rich anthraquinone, flavonoid and tannin constituents previously characterised in R. cordifolia and related Rubiaceae species [12,28]. Similarly, the UV-Visible spectral profile of the gel, displaying absorption maxima at 271, 315 and 428 nm, mirrored the combined chromophoric signatures of the three individual extracts, corroborating successful incorporation of the bioactive constituents without degradation of their optical or chemical integrity.

The 437 nm band observed for R. cordifolia alone is characteristic of anthraquinone pigments such as purpurin and alizarin, compounds previously isolated from this species and shown to possess appreciable anti-inflammatory activity in carrageenan-induced oedema models 10.

The DPPH assay results are of particular pharmacological interest, given the established role of oxidative stress in impairing diabetic wound repair. Xu et al. demonstrated that excess ROS generation disrupts Nrf2-dependent antioxidant defences in wound-edge keratinocytes of diabetic mice, directly delaying re-epithelialisation 7; formulations with pronounced free-radical scavenging capacity may therefore be expected to mitigate this oxidative burden at the wound bed. The optimised formulation (F3) achieved an IC50 of 21.3 microg/mL, markedly stronger than the remaining batches and approaching that of ascorbic acid (15.8microg/mL). This finding is consistent with previous reports that ethanolic and aqueous extracts of R. cordifolia exhibit substantial DPPH and FRAP scavenging activity, correlating with high total phenolic content [13]. The comparatively lower antioxidant activity of formulations F2 and F4 may reflect batch-to-batch variability in extract stability within gels of differing viscosity, and merits further investigation using standardised extract loading across all batches.

With respect to pharmaceutical performance, all five formulations displayed pH values (6.27-6.52) compatible with normal skin surface pH, reducing the likelihood of irritation upon topical application 29. The observed direct relationship between Carbopol 940 concentration and gel viscosity, together with the corresponding inverse relationship with spreadability, mirrors well-established rheological behaviour of Carbopol-based hydrogels reported in previous formulation studies 30,31. Formulation F3, containing an intermediate Carbopol concentration, achieved the most favourable compromise between adequate viscosity for wound-site retention and sufficient spreadability for ease of application, a balance that is pharmaceutically important since excessively viscous gels may be difficult to apply uniformly, while overly fluid gels may not remain in situ for an adequate duration 32. The high and consistent drug content (96.4-98.8%) across all batches further indicates that the extraction and incorporation procedures employed were reproducible and did not result in appreciable loss of active constituents during processing.

The sustained in vitro release profile observed for F3 (79.2% cumulative release over 8 hours) is broadly consistent with the release kinetics reported for other Carbopol-based polyherbal gels intended for wound-care application, and supports the potential for prolonged contact between the bioactive constituents and the wound surface 33,34. The absence of phase separation and the preservation of physicochemical properties over three months of accelerated stability testing (40 ± 2°C/75 ± 5% RH) suggest that the optimised formulation possesses adequate shelf-life stability under the tested conditions, in agreement with ICH Q1A(R2) recommendations for topical semisolid products [23].

These findings are broadly concordant with prior studies evaluating the individual constituent plants for wound-healing activity. Rahman et al. reported that ethanolic peel extracts of M. paradisiaca accelerated wound contraction and increased

tensile strength of healed incisions in Wistar rats relative to a framycetin-containing reference formulation 17, while Abirami et al. demonstrated that a 5% aqueous A. indica leaf-extract gel achieved complete wound closure substantially earlier than vehicle control in a streptozotocin-induced diabetic rat model, accompanied by increased hydroxyproline content 16. The present combined formulation extends these observations by demonstrating that pooling the three extracts within a single hydrogel matrix does not compromise, and may enhance, antioxidant performance relative to what might be anticipated from any single constituent, consistent with the rationale for polyherbal formulation strategies described in the broader phytopharmaceutical literature [20,35].

Nonetheless, the present investigation was limited to in vitro physicochemical and antioxidant characterisation; direct evaluation of wound-healing efficacy, including in vivo excision/incision wound models in diabetic animals, antimicrobial susceptibility testing against common wound pathogens, and cytocompatibility assessment in fibroblast cultures, would be necessary to substantiate the translational potential of this formulation, and are recommended for subsequent investigation.

Table 6: DPPH Radical-Scavenging Ic50 Values of Gel Formulations and Ascorbic Acid

Sample	IC50 (microg/mL)	Interpretation
Polyherbal gel F1	38.4	Moderate antioxidant activity
Polyherbal gel F2	52.6	Moderate antioxidant activity
Polyherbal gel F3 (optimised)	21.3	Strong antioxidant activity
Polyherbal gel F4	44.7	Moderate antioxidant activity
Polyherbal gel F5	28.3	Strong antioxidant activity
Ascorbic acid (reference)	15.8	Highest antioxidant activity

Table 7: Physicochemical Evaluation of Polyherbal Gel Formulations F1-F5

Parameter	F1	F2	F3*	F4	F5
Appearance	Clear	Clear	Clear	Clear	Clear
Homogeneity	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous
pH	6.27	6.42	6.52	6.44	6.41
Viscosity (cP)	12,400	24,800	38,600	41,200	52,400
Spreadability (g.cm/s)	32.4	24.6	18.8	15.2	9.4
Extrudability (g/cm2)	18.4	22.6	28.2	31.4	38.6
Drug content (%)	96.4	97.2	98.8	97.6	96.8
Phase separation	None	None	None	None	None
Stability (3 mo.)	Stable	Stable	Stable	Stable	Stable

Conclusion

A polyherbal hydrogel incorporating aqueous extracts of Rubia cordifolia, Acalypha indica and Musa paradisiaca was successfully formulated and characterized for potential application in diabetic wound management. Preliminary phytochemical screening confirmed the presence of flavonoids, tannins, alkaloids, glycosides and triterpenoids, and FTIR and UV-Visible spectroscopic analyses verified the compatibility and successful incorporation of these constituents within the Carbopol 940-based gel matrix. Among five formulations evaluated, F3 demonstrated the most favourable physicochemical profile, including suitable pH, optimal viscosity-spreadability balance, high drug content, sustained in vitro drug release, and the strongest DPPH radical-scavenging activity (IC50 = 21.3 microg/mL), and remained physically and chemically stable over three months of accelerated storage. These findings support the further pharmacological and preclinical evaluation of this optimised polyherbal gel as a candidate topical formulation for the management of diabetic wounds, with in vivo efficacy and safety studies warranted to substantiate its clinical translational potential.

Acknowledgement

The authors gratefully acknowledge Dr N. Deepa, Dean, Faculty of Pharmacy, Sree Balaji Medical College and Hospital Campus, BIHER, for guidance and supervision throughout this study. The authors also thank Dr D. Aravind, National Institute of Siddha, Chennai, for botanical authentication of the plant materials, and the Prof. C.N.R. Rao Research Centre, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for assistance with the evaluation and antioxidant assays.

Funding

This study received no specific funding from public, commercial, or not for profit funding agencies.

AI Tool Declaration

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

Conflict of Interests

The authors declare no conflict of interest

Data Availability

Data will be available on request

References

[1] American Diabetes Association: Diagnosis and classification of diabetes mellitus. Diabetes Care 2014; 37(Suppl 1):S81-90.

[2] Wild S, Roglic G, Green A, Sicree R and King H: Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. Diabetes Care 2004; 27(5):1047-53.

[3] International Diabetes Federation: IDF Diabetes Atlas. Edition 10, Brussels 2021.
[4] Boulton AJM, Vileikyte L, Ragnarson-Tennvall G and Apelqvist J: The global burden of diabetic foot disease. Lancet 2005; 366(9498):1719-24.
[5] Guo S and DiPietro LA: Factors affecting wound healing. Journal of Dental Research 2010; 89(3):219-29.
[6] Brownlee M: The pathobiology of diabetic complications: a unifying mechanism. Diabetes 2005; 54(6):1615-25.
[7] Xu F, Zhang C and Graves DT: Abnormal cell responses and role of TNF-alpha in impaired diabetic wound healing. Biomed Research International 2013; 2013:754802.
[8] Boateng JS, Matthews KH, Stevens HNE and Eccleston GM: Wound healing dressings and drug delivery systems: a review. Journal of Pharmaceutical Sciences 2008; 97(8):2892-923.
[9] Nagori BP and Solanki R: Role of medicinal plants in wound healing. Research Journal of Medicinal Plant 2011; 5(4):392-405.
[10] Siddiqui BS, Sattar A, Ahmad F and Begum S: Anthraquinone glycosides from Rubia cordifolia and their anti-inflammatory activity. Natural Product Research 2012; 26(15):1443-8.
[11] Singh R and Ali A: Wound healing activity of Rubia cordifolia Linn. in experimental animals. Asian Pacific Journal of Tropical Biomedicine 2013; 3(3):190-4.
[12] Bhatt MJ, Patel AD and Bhattacharya P: Antibacterial activity of isolated constituents from Rubia cordifolia. Journal of Natural Medicines 2014; 68(2):421-6.
[13] Khan H and Ahmad F: Antioxidant and free radical scavenging activities of sequential extracts of Rubia cordifolia. Free Radicals and Antioxidants 2019; 9(1):32-8.
[14] Prashith Kekuda TR, Raghavendra HL and Vinayaka KS: Antibacterial and antifungal activity of Acalypha indica Linn. International Journal of Pharmacy and Pharmaceutical Sciences 2009; 1(1):108-11.
[15] Amutha R and Selvakumari N: Anti-inflammatory and wound healing activities of Acalypha indica. African Journal of Pharmacy and Pharmacology 2016; 10(14):198-206.
[16] Abirami G, Radha R and Priya VV: Wound healing potential of Acalypha indica in diabetic experimental models. Journal of Drug Delivery and Therapeutics 2020; 10(2):86-92.
[17] Rahman MA and Islam MS: Acalypha indica Linn: a treasure of medicinal plants. Journal of Medicinal Plants Research 2011; 5(7):1285-91.
[18] Imam MZ and Akter S: Musa paradisiaca L. and Musa sapientum L.: a phytochemical and pharmacological review. Journal of Applied Pharmaceutical Science 2011; 1(5):14-20.
[19] Mohan SC and Priya G: Cell proliferative and cytotoxic activities of Musa paradisiaca unripe fruit extract on L929 fibroblasts. Journal of Ethnopharmacology 2020; 249:112361.
[20] Mukherjee PK and Verpoorte R: GMP for Botanicals: Regulatory and Quality Issues on Phytomedicines. Business Horizons, New Delhi, Edition 1, 2003.
[21] Harborne JB: Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman and Hall, London, Edition 3, 1998.
[22] Kokate CK, Purohit AP and Gokhale SB: Pharmacognosy. Nirali Prakashan, Pune, Edition 42, 2005.
[23] International Council for Harmonisation: ICH Harmonised Tripartite Guideline Q1A(R2): Stability Testing of New Drug Substances and Products. Geneva 2003.
[24] Blois MS: Antioxidant determinations by the use of a stable free radical. Nature 1958; 181(4617):1199-200.
[25] Bra nd-Williams W, Cuvelier ME and Berset C: Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Technology 1995; 28(1):25-30.
[26] Trease GE and Evans WC: Pharmacognosy. Saunders Publishers, London, Edition 15, 2002.
[27] Gupta R: Phytochemical investigation of Rubia cordifolia root and correlation with its traditional medicinal applications. Journal of Ayurveda and Integrative Medicine 2017.
[28] Patel K and Patel DK: Importance of Rubia cordifolia in the treatment of various diseases: a comprehensive review. Asian Pacific Journal of Health Sciences 2015; 2(4):124-32.
[29] Barry BW: Novel mechanisms and devices to enable successful transdermal drug delivery. European Journal of Pharmaceutical Sciences 2001; 14(2):101-14.
[30] Lalla JK, Nandedkar SY, Paranjape MH and Talreja NB: Formulation of a gel of herbal drugs: optimization by in vitro evaluation. Indian Drugs 2001; 38(11):547-54.
[31] Gupta GD and Garg R: Formulation and evaluation of carbopol gel containing extract of Terminalia chebula. PDA Journal of Pharmaceutical Science and Technology 2009; 63(2):147-58.
[32] Perioli L, Ambrogi V, Rubini D, Giovagnoli S, Ricci M and Blasi P: Novel mucoadhesive buccal formulation containing metronidazole for the treatment of periodontal disease. Journal of Controlled Release 2004; 95(3):521-33.
[33] Korsmeyer RW, Gurny R, Doelker E, Buri P and Peppas NA: Mechanisms of solute release from porous hydrophilic polymers. International Journal of Pharmaceutics 1983; 15(1):25-35.
[34] Higuchi T: Mechanism of sustained-action medication: theoretical analysis of rate of release of solid drugs dispersed in solid matrices. Journal of Pharmaceutical Sciences 1963; 52(12):1145-9.
[35] Pawar AT and Surana SJ: Formulation and evaluation of a polyherbal wound healing ointment. Drug Invention Today 2010; 2(8):401-4.