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Emulgel-Based Delivery of Phytoconstituents: Formulation, Characterisation and Stability

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ABSTRACT
Phytoconstituents are biological compounds with various therapeutic potentials, but these compounds have poor solubility and very low skin permeability. These factors, especially in topical delivery, affect the bioavailability of the agent and thereby reduce its pharmacological activities. These challenges can be overcome by formulating a drug delivery system that would increase its solubility. One such drug delivery system is emulgel. Emulgels can combine the properties of both emulsions and gels, providing an effective system for delivering lipophilic plant-derived compounds. This system can improve the stability of the drug and facilitate its penetration through the skin. Strong evidences support the enhanced delivery and improved therapeutic effectiveness of phytoconstituents like curcumin, quercetic and thymoquinone, especially in several conditions. Overall, emulgels represent a promising approach that bridges traditional phytotherapy with modern pharmaceutical technology, supporting the development of more effective topical treatments.

KEYWORDS: Phytoconstituents, Emulgel, Formulation, Characterisation

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1. INTRODUCTION

Phytoconstituents are the bioactive compounds derived from different plant extracts that have major pharmacological importance in topical drug delivery. There are various molecules like flavonoids, terpenoids, polyphenols, and alkaloids, demonstrating broad pharmacological actions. These compounds have strong anti-inflammatory, antioxidant, antimicrobial, and angiogenesis-promoting properties (Jacob et al., 2025).

These activities are particularly beneficial for treating complex chronic conditions such as ulcers, infected and non-healing wounds. However, their clinical application is often limited by poor physicochemical stability and diminished ability to penetrate the skin barrier (Janani Radhakrishnan et al., 2024).Many phytocompounds are characterised by high molecular weight and low aqueous solubility, factors that challenge their ability to penetrate the stratum corneum and reach the deeper layers of the skin for therapeutic activity (Gaikwad et al., 2021).

These limitations highlight the need for advanced delivery systems that can improve the solubility, stability, and skin permeation of lipophilic plant-derived actives. Over the past decade, several nanostructured carriers such as liposomes, nanoemulsions, and solid lipid nanoparticles have been investigated for this purpose. However, their topical use is often constrained by practical formulation issues, including low viscosity, phase separation, and poor spreadability (Romes et al., 2021).

Such properties make emulgels a hybrid delivery system that combines the solubilising potential of emulsions with the rheological advantages of gels. This dual-phase system stabilises hydrophobic phytoconstituents within a continuous gel matrix while also supporting controlled drug release, improved skin adhesion, and better patient acceptability. As a result, emulgels enhance topical delivery by improving formulation stability, increasing skin retention, and promoting localised therapeutic action in a wide range of dermatological conditions **(Figure 1)**.

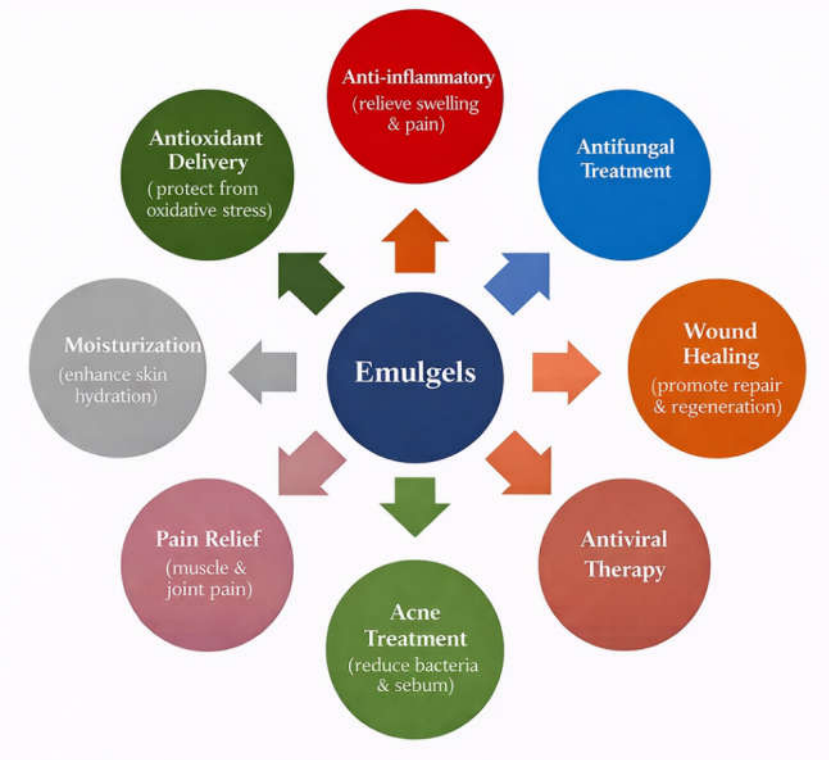

Figure 1: Indications of Emulgels as a topical drug delivery system

Emulgels are a highly effective drug delivery system because of their hybrid structure, which combines the solubilising capacity of emulsions with gel-stabilising and sustained-release properties, thereby overcoming various physicochemical limitations (Milutinov et al., 2023). This enhances the stability, increases drug loading, and improves the penetration of hydrophobic phytoconstituents across the stratum corneum (Tadić et al., 2021).

This review provides a comprehensive analysis of strategies for emulgel formulation, explaining how their structure can effectively overcome various challenges in phytoconstituent delivery. We discuss the potential of emulgels in providing therapeutic benefits of these compounds, particularly for applications like chronic wound management (Razif et al., 2025).

2. BARRIERS LIMITING TOPICAL EFFICACY OF PHYTOCONSTITUENTS

The efficacy of phytoconstituents when administered topically is hindered by the physicochemical and biological barriers of the skin. The stratum corneum is the outermost layer of the skin, forming a lipid-rich barrier that limits the entry of external substances, especially those unable to pass through its 'brick-and-mortar' structure of corneocytes inside intercellular lipids (Ren et al., 2024). This barrier allows limited diffusion of compounds, especially those with suboptimal properties for skin transport. Many plant-based compounds are poorly aqueous soluble, reducing their ability to partition into and diffuse through the hydrophilic regions of the epidermis, ultimately leading to lower bioavailability (Figure 2) (Sah, Badola, & Nayak, 2017).

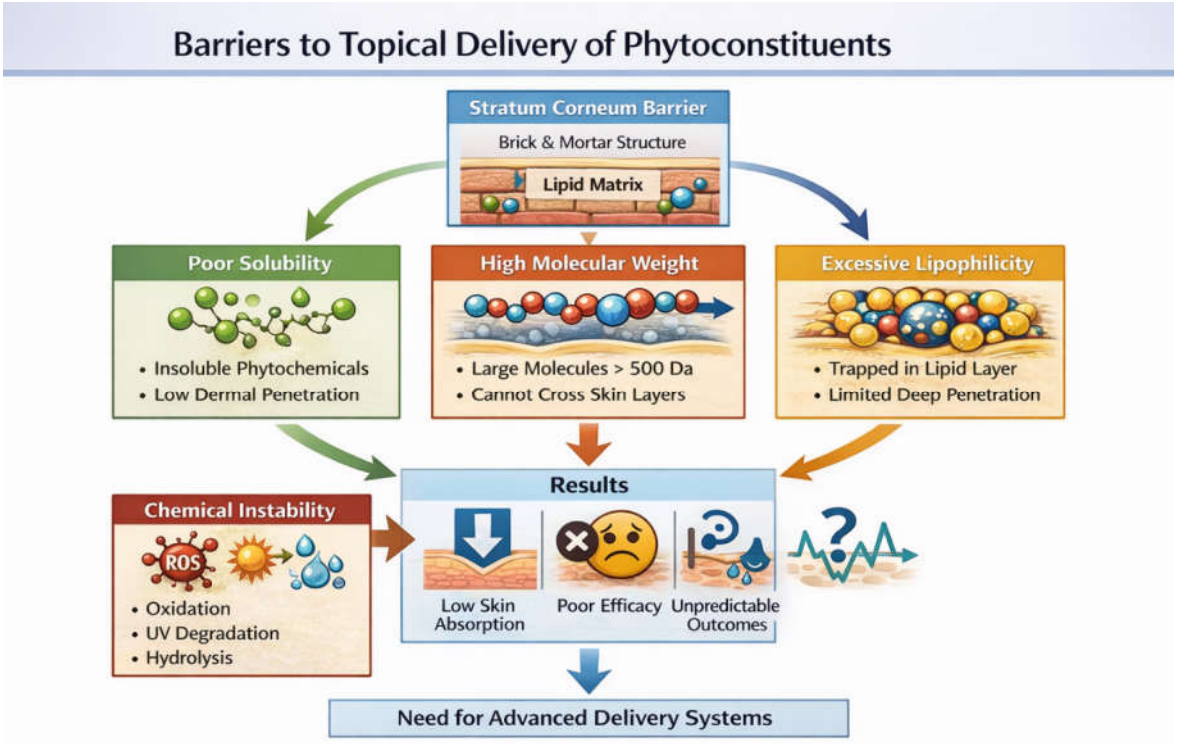

Figure 2: Physicochemical and biological skin barriers limit penetration, stability, and dermal bioavailability of phytochemicals, leading to reduced effectiveness.

High molecular weight and extensive hydrogen-bonding capacity also reduce permeation, as molecules larger than ~500 Da may not be able to cross skin layers without proper delivery system (Gugleva et al., 2021). Excessive lipophilicity (aiding initial uptake into the stratum corneum) often results in entrapment of the ligand in the upper lipid layers of the skin, preventing deeper dermal penetration necessary for therapeutic effect (Yadav et al., 2016). In addition to these, many phytoconstituents are chemically unstable and may undergo oxidation, photodegradation, or hydrolytic breakdown upon exposure to environmental factors, which further decreases their effective concentration at the site of action (Ashara et al., 2014). All these challenges limit dermal absorption and bioavailability of the compound, leading to reduced efficacy, creating the need for advanced delivery strategies to enhance the topical performance of phytoconstituents (Romes et al., 2021).

3. EMULGEL FORMULATION AND CHARACTERISATION STRATEGIES

An emulgel is one of the topical drug delivery systems that integrates the structural features of

an oil-in-water emulsion with the rheological properties of a gel (Light & Karboune, 2022). This dual-phase system enhances formulation stability, improves the solubilization of hydrophobic drugs, and provides favourable rheological and cosmetic properties for topical application (Tadić et al., 2021).

These advantages can be achieved by a detailed understanding of the formulation and characterisation of the drug delivery system. The composition of the emulsion base is a leading factor for drug stability, drug release, and therapeutic efficacy (Mohsin et al., 2016).

3.1 Standard Emulsion Base Optimisation

Emulgel is formulated by creating an emulsion system to suspend the therapeutic agent. The first step for formulating an emulgel is selecting the excipients that may effectively overcome the barriers associated with the therapeutic agent. The goal here is to create a stable emulsion that can effectively incorporate the lipophilic plant extract.

- **Phase Optimisation:**
  a. **Oil Phase Selection:** Most of the phytoconstituents are hydrophobic in nature, hence the choice of the oil component (e.g., liquid paraffin, natural fixed oils) is crucial for enhancing the solubility of the therapeutic agent. Many phytoconstituents like curcumin, quercetin, thymoquinone, etc., are lipophilic in nature and may tend to precipitate or separate if not dissolved properly. When these agents are stored, they may become instable leading to poor uniformity and reduced therapeutic efficacy. The correct oil phase for the formulation also maximises drug loading, prevents precipitation, and ensures uniform therapeutic delivery, while also supporting skin hydration, loosening stratum corneum lipid packing to promote deeper diffusion, and providing moisturising, TEWL-reducing, occlusive, and skin-softening benefits. The oil phase must be non-irritating and compatible with the skin (Jain et al., 2025).
  b. **Aqueous Phase:** This phase typically contains water and humectants (e.g., propylene glycol, glycerin). Humectants are added to enhance the final product's moisturising effect and prevent the gel from drying out upon storage or application.[6]
- **Emulsification Methods:** the conventional emulsions are formulated by mechanical agitation that results in the oil droplet formation in the range of 100 to several micrometres.[16]
- **Emulsifier System:** The emulgels are the emulsions suspended in a gel matrix; hence, an emulsifying agent or surfactant is required to suspend the system in the matrix, or the oil droplets would separate, leading to creaming or phase separation. The surfactant is required for the Hydrophilic-Lipophilic Balance (HLB) of the selected oil. The surfactants reduce interfacial tension, forming a protective barrier that prevents the large oil globules from coalescing. A carefully selected surfactant blend keeps the phytoconstituent evenly dispersed throughout the formulation, ensuring uniform drug content, consistent dosing, and improved skin delivery. Some of the common emulsifying agents used are Span and Tween, among others (Otto et al., 2009).

3.2 Gel Matrix Integration and Rheological Control

The emulsion is dispersed into a gel system, providing the required consistency for topical drug release control.

- **Gelling Agent Selection:** Agents like Carbopol (Carbomer, common for O/W systems) or cellulosic polymers (e.g., HPMC) are used to thicken the aqueous continuous phase. Carbomers are highly sensitive to pH; a neutraliser (e.g., triethanolamine) is added to initiate chain swelling and form the viscous gel network (Singh et al., 2025).
- **Rheological Properties:** The resulting emulgel must exhibit shear-thinning (thixotropic) behaviour. This property is crucial for the formulation to flow easily when applied and rubbed onto the skin (high shear) but quickly recovers its structure and viscosity upon removal of stress (low shear), ensuring it stays at the application site (Manohar & Srivastava, 2025).
- **Textural Analysis:** Objective measurements of mechanical properties, including firmness (hardness), cohesiveness, and stickiness, are used to optimise the formula for patient compliance, ensuring a non-greasy feel and good spreadability compared to thick ointments (Şentürk et al., 2025).

Once emulgel formulation parameters, such as oil phase composition, surfactant blend, and gelling agent concentration, are optimised for texture and patient acceptability, it becomes essential to verify that these design choices yield a stable and effective delivery syste (Patel et al., 2021), (Chando et al., 2023). Comprehensive physicochemical and rheological characterisation is therefore the next critical step, as it determines how the formulation behaves over time, how efficiently it delivers the incorporated phytoconstituent, and whether it maintains structural integrity under various storage conditions. These evaluations provide the scientific basis for correlating formulation components with product performance and are essential for quality control, scale-up, and regulatory approval (Chando et al., 2023).

3.3 Characterisation and Stability Assessment

Characterisation of emulgel identifies that the final product maintains its integrity and efficacy throughout its shelf life (Patel et al., 2021).

Table 1: Parameters to determine the qualities of emulgel in topical drug delivery.

Test Category	Key Parameters	Purpose	Reference
Physical Appearance	Colour, consistency, homogeneity, and presence of aggregates.	Ensures uniform mixing and cosmetic quality.	(Singh et al., 2025).
Physicochemical	pH, Drug Content (using HPLC), Globule/Droplet Size, PDI (Polydispersity Index), Zeta Potential.	Confirms API loading, skin compatibility (pH), and emulsion stability (droplet size/charge).	(Singh & Singh, 2022).
Rheological & Textural	Viscosity (using viscometer), Yield Stress, Spreadability, and Extrudability.	Determines application properties; essential for patient compliance and demonstrating shear-thinning behaviour (thixotropy).	(Karole et al., 2025)
In Vitro Release	Drug release behaviour assessed using a Franz diffusion cell or a dialysis membrane	Evaluate whether the emulgel provides sustained or controlled drug release	(Gaikwad et al., 2024)
Ex Vivo Permeation	Drug flux across excised skin (e.g., pig or human skin).	Predicts the ability of the formulation to deliver the drug into (topical effect) or across (transdermal effect) the skin barrier.	(Karole et al., 2025)
Stability Testing	Changes in pH, viscosity, particle size, and drug assay over time at various conditions (ICH guidelines).	Predicts product shelf life and identifies potential physical or chemical degradation pathways.	(Tadić et al., 2021).
Safety Testing	Dermal irritation and sensitisation testing (e.g., Draize test or human patch test).	Confirms the formulation is non-toxic and safe for prolonged skin contact.	(Schäfer et al., 2023)

Characterisation confirms the stability and safety of an emulgel, as well as its ability to deliver phytodrugs effectively to the targeted site of action. After optimisation of key parameters, the therapeutic potential of the drug becomes evident (Sabalingam & Siriwardhene, 2022).

4. THERAPEUTIC POTENTIAL OF EMULGEL FOR PHYTOCONSTITUENTS

Phytoconstituents such as flavonoids and polyphenols possess strong anti-inflammatory, antioxidant, and pro-angiogenic activities, hence increasing their demand as a valuable treatment for treating chronic skin conditions (Gaikwad et al., 2021).But, its clinical use is limited because of poor solubility and diminished skin penetration. Emulgel systems overcome these barriers by enhancing solubility, stability, and dermal permeation, ensuring higher local bioavailability and sustained release of actives like curcumin, thymoquinone, aloe vera extract, and quercetin (Puspadewi et al., 2025). These advantages lead to improved therapeutic outcomes and position emulgels as an effective bridge between traditional herbal efficacy and modern pharmaceutical performance (Figure 3).

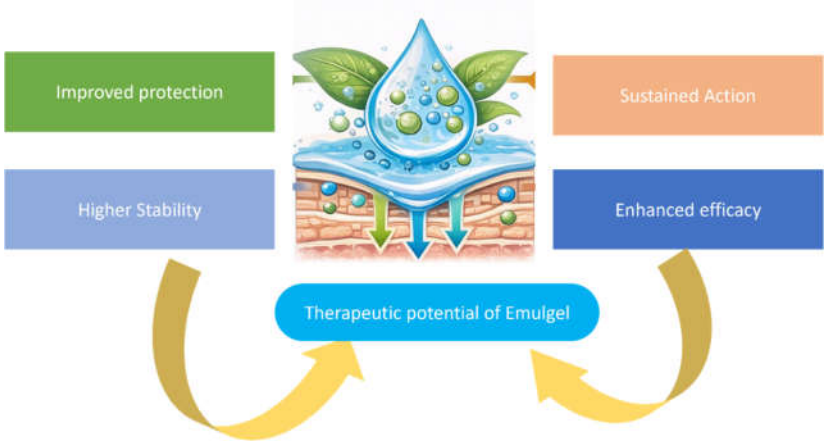

Figure 3: Emulgels enhance the topical performance of phytoconstituents by improving skin penetration, stability, sustained release, and overall therapeutic efficacy.

5. ENHANCED PERMEABILITY OF PHYTOCONSTITUENTS THROUGH EMULGEL SYSTEMS

Phytoconstituents have a broad therapeutic potential. However, they often exhibit poor skin permeability due to their high molecular weight, low aqueous solubility, and lipophilic nature, which limits their effective topical delivery (Algahtani et al., 2021). Emulgels are improving various parameters in the delivery of these phytoconstituents. They have a biphasic structure in which an emulsion is incorporated into a gel matrix, combining the advantages of both systems, offering improved solubilization, stability, and permeation of the phytochemical (Khan et al., 2020). The emulsion phase helps dissolve poorly soluble phytocompounds and promotes their movement through the lipid barrier of the skin. Meanwhile, the gel matrix ensures longer contact with the skin and enables a steady, controlled release of the active ingredients. Various mechanisms of emulgel (as mentioned in the **table** below) improve diffusion, retention, and therapeutic efficacy of plant-derived compounds in topical applications (Gugleva et al., 2021).

Excipients used in the formulation of emulgels, such as surfactants and co-surfactants (e.g., Tween 80 or Span 20), reduce interfacial tension, resulting in smaller droplets that increase surface contact with the skin. This promotes better diffusion through the stratum corneum. Additionally, the gel base enhances skin hydration, softens the keratinised layer, and improves the permeation of both hydrophilic and lipophilic constituents. Furthermore, the

occlusive property of the emulgel reduces transepidermal water loss, maintaining skin hydration and creating a favourable environment that supports continuous permeation of the active ingredients (Jain et al., 2025).

Table 2: **Mechanisms underlying enhanced skin permeability of phytoconstituents by emulgel formulations.**

Mechanism	How It Works	Result for Phytoconstituents	References
1. Dual-phase solubilization	The oil phase solubilizes lipophilic phytoconstituents (e.g., curcumin, thymoquinone, quercetin), while the aqueous phase maintains hydration of the stratum corneum.	Increases solubility and partitioning of actives into skin layers.	(Prow et al., 2011)
2. Stratum corneum hydration	The gel retains moisture on the skin surface, softening keratin and loosening the lipid matrix.	Enhances diffusion of phytoconstituents through the outer skin barrier.	(Babriwal et al., 2025)
3. Penetration enhancers in oil phase	Components like oleic acid, isopropyl myristate, or surfactants (Tween, Span) disrupt lipid bilayers in the stratum corneum.	Reduces resistance to drug permeation.	(Mamgain et al., 2025)
4. Small droplet size (nano- or microemulgel)	Nano-sized droplets (~50–200 nm) have high surface area and close contact with skin.	Facilitates better drug absorption and reservoir formation in skin layers.	(Nagaraja et al., 2021)
5. Controlled release through gel network	The gel matrix slows the release, maintaining a concentration gradient across skin over time.	Sustained drug permeation and prolonged local effect.	(Singh et al., 2025).
6. Increased thermodynamic activity	The system's composition (emulsion + gel) maintains a high chemical potential of the phytoconstituent.	Drives continuous diffusion across the skin.	(Şentürk et al., 2025)
7. Occlusive effect	The gel layer reduces transepidermal water loss, increasing hydration and permeability.	Boosts penetration for both hydrophilic and lipophilic actives.	(Milutinov et al., 2023)

Supporting these proposed mechanisms, multiple preclinical studies have reported notable enhancements in in-vitro drug release, ex-vivo permeation, and in-vivo therapeutic performance of emulgels containing phytoconstituents. Table 3 provides an overview of key findings from representative studies.

Table 3: Comparative performance of phytoconstituent-based emulgel formulations highlighting their enhanced permeation, controlled release, and therapeutic efficacy

S.No	Formulation	*Ex-vivo /In-vivo* permeation	*In-vitro* release	Therapeutic potential	Reference
	Curcumin Nanoemulgel (CuNE)	**Skin deposition** of curcumin from the CuNE was **1161.54 ± 2.78 µg/cm²**, compared to **179.47 ± 1.56**	CuNE- 85% release of curcumin Aq suspension- 10% release within 12 hours The CuNE demonstrated a	The quality of wound healing (based on granulomatous mass, inflammatory cells, and collagen fibers) ranked as	(Algahtani et al., 2021)

		µg/cm² from the curcumin gel.	**significantly higher (p < 0.05)** drug release	follows: **Curcumin NEG (G-IV) >** Silver Sulfadiazine Cream (G-II) > Conventional Curcumin Gel (G-III).	
	Thymoquinone Loaded Topical Nanoemulgel (TQNE)	Skin deposition studies revealed that TMQ-NEG provided a significantly greater amount of TMQ (965.65 ± 12.84 ug/cm2) compared to the TMQ-gel (150.93 ± 1.80 ug/cm2).	All tested **TMQ-NE formulations** demonstrated a **significantly higher** ($p < 0.05$) in-vitro release of TMQ when compared to the simple aqueous TMQ suspension.	The time it took for complete **epithelization** (full closure) of the wounds varied across the groups: Control: **16.6 ±0.57** days; Ag-Sulfadiazine: **11.66 ±1.52** days; TMQ-gel: **14.33 ±0.57** days; TMQ-NEG: **10.33 ±0.57** days	(Algahtani et al., 2021)
	Nanoemulgel loaded with ginger oleoresin and lipid guggul extract (GOR-LGE NEG)			The GOR-LGE NEG formulation modulated the cellular immune response by significantly suppressing the levels of pro-inflammatory markers (IL-6 and TNF-a) while elevating the anti-inflammatory marker IL-10.	(Maleki et al., 2023)
	Ocimum basilicum- based emulgel		Emulgel release over 250 min: 0% (0 min) > 81.71% (250 min), with values of 50%, 57.3%, 65.7%, and 73.2% recorded at 50, 100, 150, and 200 minutes, respectively.	While both active treatments significantly increased wound contraction compared to the control ($p < 0.05$), the rate of contraction between the extract-treated and standard-treated groups was statistically comparable ($p > 0.05$).	(Khan et al., 2020).

These outcomes are essential in wound healing where anti-inflammatory, antioxidant and tissue regeneration responses of the drug depends on the delivery system. The emulgel system can increase bioavailability of the phytoconstituent to modulate the tissue repair process (Dhiraj et al., 2024).

6. THERAPEUTIC EFFICACY

6.1 Modulating the Inflammatory and Proliferative Phases of Wound Repair

Following the demonstration that emulgels successfully deliver phytoconstituents across the skin barrier, the review must transition to the pharmacological efficacy of these delivered compounds, specifically in the context of chronic wound healing (Manohar & Srivastava, 2025). The key advantage of emulgels is not just delivery, but enabling the actives to reach therapeutic concentrations where they can actively correct the pathological state of a non-healing wound.

6.2 Resolving Chronic Inflammation (The Phagocytic Phase)

A persistent inflammatory phase characterises chronic wounds, often referred to as being 'stuck' in a destructive cycle of high oxidative stress and tissue breakdown. Emulgels carrying specific phytoconstituents offer a targeted intervention to resolve this state (Algahtani et al., 2021).

6.3 Counteracting Oxidative Stress: Phytoconstituent-loaded emulgels can help manage the persistent oxidative stress seen in chronic wounds by improving the local delivery of plant-based antioxidants such as curcuminoids and quercetin. By enhancing transport to the wound site, these systems support the scavenging of excessive reactive oxygen species (ROS) generated during inflammation. Evidence in the literature should prioritise studies that report measurable reductions in oxidative stress markers such as lipid peroxidation or TBARS in wound tissue or exudate compared with untreated controls (Algahtani et al., 2021).

6.4 Cytokine Suppression and Anti-MMP Activity: Emulgel system is essential for suppressing chronic inflammation. The sustained presence of phytomedicine facilitates the downregulation of pro-inflammatory cytokines (TNF-α, IL-6) and inhibits the activity of Matrix Metalloproteinases (MMPs). By decreasing ECM breakdown, emulgel treatments (e.g., those with *Aloe Vera* or *Calendula* extracts) effectively help in tissue preservation and repair.

6.5 Stimulating the Constructive Proliferative Phase (Tissue Regeneration): The inflammatory phase in the wound healing process is followed by subsequent phases of proliferation. In these stages, the emulgel must facilitate the process of angiogenesis, tissue remodelling and epithelialization (Khan et al., 2020).

6.6 Promoting Angiogenesis: Emulgels are promising carriers for pro-angiogenic phytoconstituents that are essential for managing ischemia-associated chronic wounds. They improve local delivery and enhance the therapeutic activity of compounds such as asiaticoside, which has been reported to upregulate key angiogenic mediators, including vascular endothelial growth factor (VEGF). Evidence from preclinical studies should prioritise histological outcomes, particularly increases in micro vessel density, to confirm that improved emulgel delivery translates into functional angiogenesis and more effective tissue repair.

6.7 Antimicrobial Defence: Chronic wounds are prone to persistent microbial colonisation, requiring delivery systems that can effectively reduce bacterial load. Emulgels support this by locally delivering plant-derived antimicrobials such as clove and tea tree oils in a sustained manner, maintaining therapeutic concentrations at the wound site and limiting infection-related healing delays. Overall, evidence shows that emulgels not only enhance the penetration and stability of phytoconstituents but also translate these advantages into improved wound-healing outcomes (Hashempur et al., 2025).

7. REGULATORY AND INDUSTRIAL PERSPECTIVES IN THE DEVELOPMENT OF PHYTOCONSTITUENT-BASED EMULGELS

After the development of these emulgel systems, the main challenge is the conversion of laboratory-scale systems into a commercial pharmaceutical or cosmeceutical product. This requires approval from various regulatory

agencies such as the US FDA, European Medicines Agency (EMA), and CDSCO in India (Bhatt, 2016), (European Medicines Agency [EMA], 2026), (U.S. Food and Drug Administration [FDA], 2026). Although phytoconstituents are perceived as a safer option due to their natural origin, this doesnot make the drug clinically effective. Hence, these drugs must be tested thoroughly for reproducibility, efficacy, safety and tolerability through validated analytical methods, stability studies, and toxicological evaluations (National AYUSH Mission, 2026).

A key regulatory challenge in phytomedicine is the inherent variability of plant materials, as phytochemical composition can vary with geographic source, harvesting season, processing (drying/extraction), storage conditions, and chemotype. Safety is another concern for topical agents, especially those used chronically (Katiyar et al., 2023).

Hence, regulatory frameworks require topical formulations to be assessed for dermal irritation, sensitisation, cytocompatibility, and local toxicity using methods such as the Draize test, human repeat-insult patch testing (HRIPT), and in-vitro viability assays (e.g., MTT or resazurin). For nano-enabled systems, further evaluation is needed to examine nanoparticle skin interactions, possible systemic exposure, and the potential for long-term accumulation World Health Organization (WHO, 2018). The growing demand for phytomedicines and phytochemicals for pharmaceutical and cosmeceutical use has made regulatory guidelines even more crucial for these substances for broader adoption and commercial success.

8. FUTURE PROSPECTS OF PHYTOCONSTITUENT-LOADED EMULGEL SYSTEMS

In the drug delivery system, topical and transdermal delivery of phytoconstituents have became an important aspect of therapeutic development. Topical and transdermal drugs have shown potential for advancement in various fields as anti-inflammatory, antiseptic and antimicrobial agents. The only limiting factor for these agents is the solubility and permeability within the skin layers (Satya Lakshmi et al., 2021). One promising direction is the integration of lipophilic agents in stimuli-responsive or "smart" polymers encased in gel matrices, enabling controlled drug release. Such innovative techniques would allow phytomedicines to be delivered to the site of action in the concentration required for drug action.[19] Advances in the techniques of drug delivery systems using high throughput and computational modelling are expected to streamline the optimisation of systems like emulgel, allowing researchers to predict rheological behaviour, droplet stability, and permeation efficiency with greater accuracy (Anand et al., 2019).

If these emulgel systems are paired with nanotechnology, it may open doors to numerous future avenues in clinical translation of phytomedicines. Though large-scale, randomised clinical trials are needed to establish long-term safety, dermal tolerability, pharmacokinetics, and comparative efficacy of these agents against conventional formulations. Such research will also help regulatory agencies formulate clearer guidelines for herbal nanocarriers, ultimately facilitating their approval and market entry. Additionally, the incorporation of novel penetration enhancers, bioadhesive polymers, and biodegradable nanostructures may further expand the range of phytochemicals amenable to topical delivery, enhancing their stability and therapeutic potential (Oberdörster et al., 2005). Full-scale pilot studies are required to convert laboratory-sized products into large-scale industrial manufacturing to align with GMP standards. The growing demand for natural products has fuelled the research on these novel techniques and also led to integration of these with nanotechnology to futher boast clinical outcomes.

9. CONCLUSION

In topical drug deliver phytomedicines pose many challenges related to stability bioavailibilkty and solubility. In these cases, emulgels are a promising delivery system to enhance skin penetration and efficacy of the therapeutic agent. Emulgels combine the properties of an emulsion with gel, increasing the embollient and humectant properties of topical

phytodrugs. This improves clinical outcomes in a lot of diseases and serves as a novel technique for wound healing, inflammation, and skin repair. Future work should focus on clinical studies, standardisation, and scalable manufacturing to support broader therapeutic and commercial use of these phytomedicines.

REFERENCES

Algahtani, M. S., Ahmad, M. Z., Nourein, I. H., et al. (2021). Preparation and characterization of curcumin nanoemulgel utilizing ultrasonication technique for wound healing: In vitro, ex vivo, and in vivo evaluation. *Gels*. https://doi.org/10.3390/gels7040213

Algahtani, M. S., Ahmad, M. Z., Shaikh, I. A., Abdel-Wahab, B. A., Nourein, I. H., & Ahmad, J. (2021). Thymoquinone loaded topical nanoemulgel for wound healing: Formulation design and in vivo evaluation. *Molecules, 26*. https://doi.org/10.3390/molecules26133863

Ali Khan, B., Ullah, S., Khan, M. K., Alshahrani, S. M., & Braga, V. A. (2020). Formulation and evaluation of *Ocimum basilicum*-based emulgel for wound healing using an animal model. *Saudi Pharmaceutical Journal, 28*, 1842–1850.

Anand, K., Ray, S., Rahman, M., Shaharyar, A., Bhowmik, R., Bera, R., & Karmakar, S. (2019). Nano-emulgel: Emerging as a smarter topical lipidic emulsion-based nanocarrier for skin healthcare applications. *Recent Patents on Anti-Infective Drug Discovery, 14*, 16–35.

Annex 1: WHO guidelines on good herbal processing practices for herbal medicines. (World Health Organization).

Ashara, K. C., Paun, J. S., Soniwala, M. M., Chavada, J. R., & Mori, N. M. (2014). Micro-emulsion based emulgel: A novel topical drug delivery system. *ChemInform*. https://doi.org/10.1002/chin.201434272

Bhatt, A. (2016). Phytopharmaceuticals: A new drug class regulated in India. *Perspectives in Clinical Research, 7*, 59.

Botanical drug development: Guidance for industry. (n.d.). U.S. Food and Drug Administration. Retrieved February 15, 2026, from https://www.fda.gov/regulatory-information/search-fda-guidance-documents/botanical-drug-development-guidance-industry

Chando, A., Basudkar, V., Gharat, S., Momin, M., & Khan, T. (2023). Development and preclinical assessment of nanoemulgel loaded with phytoconstituents for the management of rheumatoid arthritis. *Drug Delivery and Translational Research, 14*, 524–541.

Dhiraj, M., Kale, P. R., & Mane, S. B. (2024). A short review: Emulgel approach to formulation development. *International Journal of Pharmaceutical Research and Applications, 9*, 1055.

Gaikwad, A. R., Ahire, K. D., Gosavi, A. A., Salunkhe, K. S., & Khalkar, A. (2021). Phytosome as a novel drug delivery system for bioavailability enhancement of phytoconstituents and its applications: A review. *Journal of Drug Delivery and Therapeutics, 11*, 138–152.

Gaikwad, N. S., Aher, R., Bagul, M., Patil, D., Sharma, Y., & Sonawane, D. (2024). A comprehensive review on emulgel as a topical drug delivery system. *International Journal of Pharmaceutical Sciences, 2*, 1398–1405.

Gourav, B., Babriwal, G., Meena, R., Mishra, R., Vishvakarma, R., Nandwana, A., & Pawar, R. (2025). Formulation and evaluation of ophthalmic in situ gel for treatment of fungal keratitis. *International Journal of Pharmaceutical Sciences*. https://doi.org/10.5281/zenodo.15126830

Gugleva, V., Ivanova, N., Sotirova, Y., & Andonova, V. (2021). Dermal drug delivery of phytochemicals with phenolic structure via lipid-based nanotechnologies. *Pharmaceuticals, 14*. https://doi.org/10.3390/ph14090837

Hashempur, M. H., Ghorat, F., Karami, F., Jahanbin, A., Nouraei, H., Abbasi, M., Jafari, M., Zare, A., Barzegar, S., & Zareshahrabadi, Z. (2025). Topical delivery systems for plant-derived antimicrobial agents: A review of current

advances. *International Journal of Biomaterials, 2025*, 4251091.

Herbal medicinal products: Scientific guidelines. (n.d.). European Medicines Agency. Retrieved February 15, 2026, from https://www.ema.europa.eu

Jacob, S., Kather, F. S., Boddu, S. H. S., Rao, R., & Nair, A. B. (2025). Vesicular carriers for phytochemical delivery: A comprehensive review of techniques and applications. *Pharmaceutics*. https://doi.org/10.3390/pharmaceutics17040464

Jain, A., Kumar, P., Verma, A., Mohanta, B. C., Ashique, S., Pal, R., Kumar, S., & Mishra, N. (2025). Emulgel: A cutting edge approach for topical drug delivery system. *Current Drug Research Reviews, 17*, 217–236.

Karole, S., Malgaya, K., Shah, N. P., Shukla, K., Singh, R., Roy, S., Singh, R., & Shaha, A. (2025). Development and evaluation of clobetasol propionate nanoemulgel with babchi oil for fungal infections. *South East European Journal of Public Health*, 4205–4225.

Katiyar, C., Chakrabarty, A., Dubey, S., Pandey, P., Tumulu, M., & Narwaria, A. (2023). Enhancing quality of Ayush products – Strategies and efforts of the Ministry of Ayush and Ayush industry. *Journal of Research in Ayurvedic Sciences, 7*, 73.

Light, K., & Karboune, S. (2022). Emulsion, hydrogel and emulgel systems and novel applications in cannabinoid delivery: A review. *Critical Reviews in Food Science and Nutrition, 62*, 8199–8229.

Mahesh Patel, B., Kuchekar, A. B., & Pawar, S. R. (2021). Emulgel approach to formulation development: A review. *Bioscience Biotechnology Research Asia, 18*, 459–465.

Maleki, H., Azadi, H., Yousefpoor, Y., Doostan, M., Doostan, M., & Farzaei, M. H. (2023). Encapsulation of ginger extract in nanoemulsions: Preparation, characterization and in vivo evaluation in rheumatoid arthritis. *Journal of Pharmaceutical Sciences, 112*, 1687–1697.

Mamgain, S., Rawat, M., Singh, A., & Singh, V. K. (2025). Preparation and assessment of polyherbal emulgel: A research-based approach to topical herbal therapy. https://doi.org/10.33545/26174693.2025.v9.i7b.4709

Manohar, G., & Srivastava, P. (2025). Translational potential of nanoemulsion in wound healing: From discovery to product commercialization. *Next Nanotechnology, 7*, 100187.

Milutinov, J., Krstonošić, V., Ćirin, D., & Pavlović, N. (2023). Emulgels: Promising carrier systems for food ingredients and drugs. *Polymers*. https://doi.org/10.3390/polym15102302

Mohsin, S., Akhtar, N., Mahmood, T., Khan, H., & Mustafa, R. (2016). Formulation and stability of topical water in oil emulsion containing corn silk extract. *Tropical Journal of Pharmaceutical Research, 15*, 1115–1121.

Nagaraja, S., Basavarajappa, G. M., Attimarad, M., & Pund, S. (2021). Topical nanoemulgel for the treatment of skin cancer: Proof-of-technology. *Pharmaceutics*. https://doi.org/10.3390/pharmaceutics13060902

Oberdörster, G., Maynard, A., Donaldson, K., et al. (2005). Principles for characterizing the potential human health effects from exposure to nanomaterials: Elements of a screening strategy. *Particle and Fibre Toxicology, 2*, 8.

Operational guidelines medicinal plants. (n.d.). National AYUSH Mission. Retrieved February 14, 2026, from https://namayush.gov.in

Otto, A., Du Plessis, J., & Wiechers, J. W. (2009). Formulation effects of topical emulsions on transdermal and dermal delivery. *International Journal of Cosmetic Science, 31*, 1–19.

Patel, B. M., Kuchekar, A. B., & Pawar, S. R. (2021). Emulgel approach to formulation development: A review. *Bioscience Biotechnology Research Asia, 18*, 459–465.

Prow, T. W., Grice, J. E., Lin, L. L., et al. (2011). Nanoparticles and microparticles for skin drug delivery. *Advanced Drug Delivery Reviews, 63*, 470–491.

Puspadewi, R., Milanda, T., Muhaimin, M., & Chaerunisaa, A. Y. (2025). Nanoparticle-encapsulated plant polyphenols and

flavonoids as an enhanced delivery system for anti-acne therapy. *Pharmaceuticals*. https://doi.org/10.3390/ph18020209

Radhakrishnan, J., Kennedy, B. E., Noftall, E. B., Giacomantonio, C. A., & Rupasinghe, H. P. V. (2024). Recent advances in phytochemical-based topical applications for the management of eczema: A review. *International Journal of Molecular Sciences*. https://doi.org/10.3390/ijms25105375

Razif, R., Fadilah, N. I. M., Ahmad, H., Looi, Q. H., Maarof, M., & Fauzi, M. B. (2025). Asiaticoside-loaded multifunctional bioscaffolds for enhanced hyperglycemic wound healing. *Biomedicines*. https://doi.org/10.3390/biomedicines13020277

Ren, Y. H., Song, F. Y., Zhao, J. Y., Liang, B. W., & Peng, L. H. (2024). Unlocking the stratum corneum barrier to skin penetration for the transdermal delivery of cyclovirobuxine D. *Pharmaceutics*. https://doi.org/10.3390/pharmaceutics16121600

Romes, N. B., Abdul Wahab, R., & Abdul Hamid, M. (2021). The role of bioactive phytoconstituents-loaded nanoemulsions for skin improvement: A review. *Biotechnology and Biotechnological Equipment, 35*, 711–729.

Sabalingam, S., & Siriwardhene, M. A. (2022). A review on emerging applications of emulgel as topical drug delivery system. *World Journal of Advanced Research and Reviews*, 452–463.

Sah, S. K., Badola, A., & Nayak, B. K. (2017). Emulgel: Magnifying the application of topical drug delivery. *Indian Journal of Pharmaceutical and Biological Research, 5*, 25–33.

Satya Lakshmi, S., Divya, R., Srinivasa Rao, Y., Kamala Kumari, P. V., & Deepthi, K. (2021). Emulgel—Novel trend in topical drug delivery system: Review article. *Research Journal of Pharmacy and Technology, 14*, 2903–2906.

Schafer, N., Balwierz, R., Biernat, P., Ochędzan-Siodłak, W., & Lipok, J. (2023). Natural ingredients of transdermal drug delivery systems as permeation enhancers through the stratum corneum. *Molecular Pharmaceutics, 20*, 3278–3297.

Şentürk, T. B., Barak, T. H., Çağlar, E. Ş., Saldamlı, E., Özdemir Nath, E., & Özdemir, Z. Ö. (2025). A bioactive emulgel formulation of *Equisetum telmateia* extract: Antioxidant activity, skin enzyme inhibition, and permeation kinetics. *Gels*. https://doi.org/10.3390/gels11080662

Singh, K., Gupta, J. K., Jain, D., Sharma, M. C., Kumar, S., Chaudhary, R., & Mishra, S. (2025). Emulgel-based formulations of clobetasol propionate: Formulation development, characterization, and pharmacological evaluation. *Pharmaceutical Nanotechnology, 13*, 842–850.

Singh, S., & Singh, I. (2022). Evolving implementation of emulgel as a topical drug delivery system: A systematic review. *Current Research in Pharmaceutical Sciences, 12*, 121–131.

Tadić, V. M., Žugić, A., Martinović, M., Stanković, M., Maksimović, S., Frank, A., & Nešić, I. (2021). Enhanced skin performance of emulgel vs. cream for topical delivery of herbal actives. *Pharmaceutics*. https://doi.org/10.3390/pharmaceutics13111919

Yadav, S. K., Mishra, M. K., Tiwari, A., & Shukla, A. (2016). Emulgel: A new approach for enhanced topical drug delivery. *International Journal of Current Pharmaceutical Research, 9*, 15.