

# A Review on Polyherbal Gel Formulations: An Emerging Strategy for Enhancing the Therapeutic Potential of Combined Herbal Extracts

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Date of Submission: 01-11-2025

Date of Acceptance: 10-11-2025

## ABSTRACT

Polyherbal formulations have gained significant attention in recent years due to their synergistic therapeutic potential and ability to target multiple pathological pathways simultaneously. Gels, being semisolid systems, serve as an ideal vehicle for topical application of herbal bioactives, offering enhanced patient compliance, localized drug delivery, and minimal systemic side effects. This review focuses on the formulation, development, and comprehensive evaluation of polyherbal gel preparations containing multiple plant extracts designed to enhance the combination therapy of active phytoconstituents. The article elaborates on the rationale behind polyherbal therapy, formulation techniques, selection of polymers and excipients, physicochemical and biological evaluation parameters, and the importance of standardization and stability studies. Emphasis is placed on the synergistic interactions among herbal components that lead to superior therapeutic outcomes compared to single-herb formulations.

**Keywords:** polyherbal gel, topical delivery, plant extracts, combination therapy, formulation, evaluation, permeation, standardization.

## I. INTRODUCTION

Topical gels are popular vehicles for delivering phytoconstituents to the skin owing to patient acceptability, ease of application, and tunable physicochemical properties. Polyherbal formulations combine extracts from two or more

plants to produce additive or synergistic therapeutic effects — relevant for inflammatory, infectious, analgesic, wound-healing, and dermatological conditions (Dev et al., 2019). Combining extracts can target multiple disease pathways, permit lower doses of each constituent, and reduce adverse events (Chaachouay, 2025).

In recent years, there has been a significant global resurgence of interest in herbal and natural products due to their broad pharmacological activities, reduced side effects, and cultural acceptance. Herbal medicines, which contain bioactive phytoconstituents derived from medicinal plants, have been used for centuries in various traditional systems such as Ayurveda, Siddha, Unani, and Traditional Chinese Medicine (TCM) (Shah et al., 2025). Among various dosage forms, topical herbal formulations—particularly gels—have gained increasing attention because they provide localized therapeutic effects, minimize systemic exposure, and improve patient compliance through easy application and aesthetic acceptability (Agrawal et al., 2024).

## II. ROLE OF HERBAL EXTRACTS AND ACTIVE PHYTOCONSTITUENTS

Each plant extract incorporated in a polyherbal gel contributes a set of bioactive phytochemicals responsible for specific therapeutic outcomes. Some examples are:

Plant Extract	Major Active Phytoconstituents	Therapeutic Role
Aloe vera	Aloin, aloesin, polysaccharides	Moisturizing, wound-healing, anti-inflammatory

Curcuma longa (Turmeric)	Curcumin, demethoxycurcumin	Antioxidant, anti-inflammatory, antimicrobial
Azadirachta indica (Neem)	Azadirachtin, nimbin, quercetin	Antibacterial, antifungal, anti-acne
Calendula officinalis	Triterpenoids, flavonoids	Healing, anti-inflammatory, soothing
Camellia sinensis (Green tea)	Catechins, EGCG	Antioxidant, antiaging, UV protection
Ocimum sanctum (Tulasi)	Eugenol, ursolic acid	Antimicrobial, anti-inflammatory, antioxidant
Centella asiatica	Asiaticoside, madecassoside	Collagen synthesis, wound-healing, rejuvenation

### III. RATIONALE FOR POLYHERBAL COMBINATION THERAPY

#### 3.1 Synergy and multi-target actions:

Many pathological conditions such as chronic wounds, eczema, psoriasis, acne, and microbial infections are multifactorial, involving a complex interplay of oxidative stress, inflammation, microbial invasion, and delayed tissue regeneration. A single therapeutic agent is often insufficient to modulate these multiple biochemical and cellular pathways effectively (Mataret et al., 2023). Polyherbal formulations, which integrate two or more plant extracts with diverse phytoconstituents, offer a synergistic approach. The combined action of different bioactive molecules—such as flavonoids, alkaloids, terpenoids, and phenolic compounds—can simultaneously target multiple mechanisms (Chaachouay, 2025). For instance, one herbal extract may exert strong anti-inflammatory activity, another may demonstrate potent antimicrobial or antioxidant effects, while a third could promote collagen synthesis and wound contraction. When used together, these extracts can produce additive or synergistic outcomes that surpass the efficacy of single-herb preparations. This multi-target approach not only enhances therapeutic effectiveness but also addresses the root causes of complex diseases more comprehensively (Zhou et al., 2016).

#### 3.2 Pharmacokinetic complementarity:

Polyherbal combinations may also improve pharmacokinetic profiles through mutual interactions among constituent phytochemicals. One extract can act as a natural bioenhancer, increasing the permeability, solubility, or metabolic stability of another (Sulaiman et al., 2021). For example, saponins or essential oils present in certain herbs can enhance transdermal absorption of co-administered constituents by modifying stratum corneum lipid structures or inhibiting metabolizing enzymes. Moreover, some phenolic compounds can inhibit enzymes responsible for degradation of active molecules, thereby prolonging their retention time in the target tissue. Such pharmacokinetic complementarity ensures optimal delivery of active constituents to the site of action, resulting in improved bioavailability and sustained therapeutic action (Gerber et al., 2018).

#### 3.3 Dose-sparing and tolerability:

The synergistic interaction among phytoconstituents allows for a reduction in the required dose of individual extracts without compromising overall efficacy. This dose-sparing effect minimizes the likelihood of local or systemic adverse effects such as skin irritation, allergic responses, or toxicity (Chaachouay, 2025). Since each herb contributes a specific pharmacological role within the formulation, the therapeutic burden is distributed across multiple components rather than relying on a single active compound. This balanced composition enhances tolerability, making polyherbal formulations safer and more

suitable for long-term use in topical and systemic therapy alike (Rahim, 2024).

### 3.4 Heritage and ethnopharmacology:

The practice of combining herbs has deep roots in traditional systems of medicine such as Ayurveda, Siddha, Unani, and Traditional Chinese Medicine (TCM). These formulations were originally designed based on centuries of empirical evidence and the holistic principle that a disease must be treated by addressing both symptoms and underlying imbalances. Traditional knowledge offers valuable insights into compatible plant combinations, proportions, and therapeutic indications (Kroenke, 2014). However, modern scientific validation is essential to ensure reproducibility, safety, and mechanistic understanding. Phytochemical standardization, bioassay-guided fractionation, and mechanistic pharmacology can be employed to verify the rationale behind traditional combinations. This integration of ethnopharmacological wisdom with contemporary pharmaceutical science provides a rational and evidence-based foundation for developing effective and stable polyherbal formulations (Balkrishna et al., 2024).

## IV. EXTRACTION METHODS FOR COMBINATION THERAPY

**4.1 Solvent choice:** Water, ethanol, hydroalcoholic, or green solvents selected to solubilize targeted constituents. For topical use, ethanol or hydroalcoholic extracts are common because they provide good solubility and antiseptic properties (Hoang et al., 2021).

**4.2 Methods:** Maceration, percolation, Soxhlet, ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), supercritical fluid extraction (SFE) — choose based on heat sensitivity and polarity of markers (Kalaskaret al., 2025).

**4.3 Concentration and drying:** Rotary evaporation, lyophilization for thermolabile compounds. Produce reproducible dry extracts or concentrated tinctures (Alamgir, 2017).

**4.4 Compatibility testing:** Test extract–extract compatibility (pH, color changes, precipitation) before final formulation (Kolisnyket al., 2022).

## V. GEL

A gel is a semisolid combination of a three-dimensional matrix of cross-linked materials. Several substances create a matrix in a liquid dispersion medium and form a gel. Organic and inorganic macromolecules act as formational units in preparing gel (Izadi et al., 2023). According to USP (2021), “A gel is solid or semisolid. Gels can be classified into two groups, chemical and physical gels. Chemical gels are usually covalently cross-linked gels, while physical gels consist of small molecules or molecular chains that are physically cross-linked into networks, or solutions, or colloidal dispersions that are stiffened by a gelling agent.” A gel is a two-phase system in which the inorganic particles are present in an insoluble state, but these particles are uniformly distributed throughout the external phase. However, the large organic particles are freely available in the external phase. These phases are then joined together in stretchable chains (Rathod and Mehta 2015).

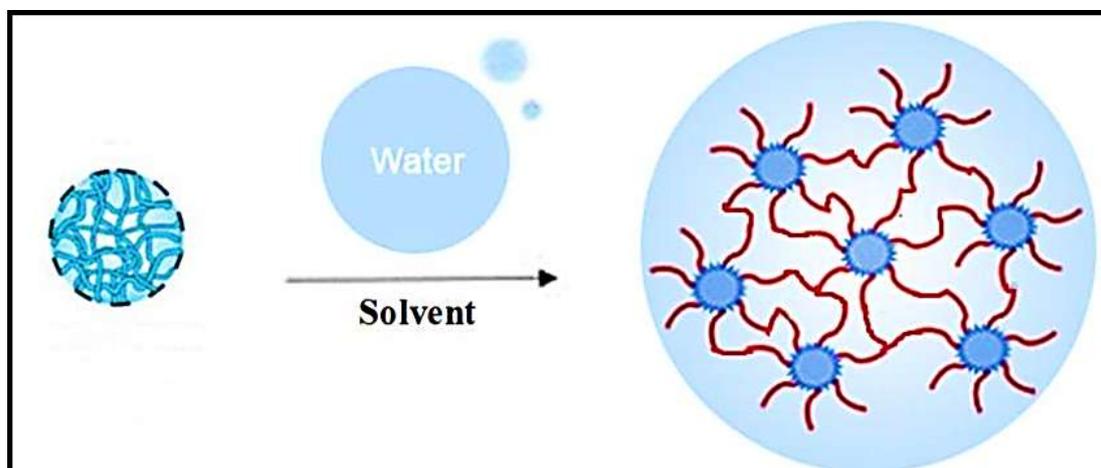


Figure 1:- Gel matrix

Gelling agent, also known as a gelator, is a natural, synthetic or semi-synthetic polymer or low molecular weight small molecule which is added to an organic, inorganic, or aqueous solvent or in a solvent system to prepare a gel (Un Nabi et al., 2016).

### 5.1 Gel types

#### A. Hydrogels:

Hydrogels are semisolid systems comprising hydrophilic polymers that form a three-dimensional network capable of holding large amounts of water. They are suitable for incorporating hydrophilic or water-soluble herbal extracts. Hydrogels are non-greasy, easily washable, and provide a cooling effect, making them ideal for topical applications (Kulawik-Pióro and Miastkowska 2021). Commonly used hydrogel-forming polymers include:

- **Carbomers (Carbopol 934, 940, 974):** Synthetic high-molecular-weight polymers of acrylic acid crosslinked with polyalkenyl ethers. They provide excellent clarity, viscosity, and stability. Neutralization with agents such as triethanolamine converts the dispersion into a smooth gel structure (Shamlooh, 2020).
- **Hydroxypropyl Methylcellulose (HPMC):** A nonionic cellulose derivative that offers good film-forming properties, biocompatibility, and stability. It provides a smooth texture and can be used alone or in combination with other polymers (Romão et al., 2022).
- **Sodium Carboxymethyl Cellulose (NaCMC):** A water-soluble polymer that imparts viscosity and contributes to the controlled release of active compounds (Kamalyet al., 2016).
- **Xanthan Gum and Guar Gum:** Naturally derived polysaccharides used for thickening and stabilizing formulations, particularly in herbal gels (Bora et al., 2025).
- **Poloxamers (Pluronic F-127):** Thermoreversible polymers that exist as a liquid at low temperatures and form gels upon warming, useful for controlled release and temperature-sensitive systems (Taylor et al., 2017).

Hydrogel systems are ideal for polyherbal formulations containing hydrophilic plant extracts, as they provide a suitable aqueous environment that helps preserve the activity of polar phytochemicals

like flavonoids, phenolic acids, and tannins (Usama et al., 2024).

#### B. Organogels/Semisolid systems:

Organogels consist of a nonpolar organic phase (such as isopropyl myristate or mineral oil) immobilized by an organogelator (e.g., sorbitanmonostearate, lecithin, or cholesterol). They are particularly useful for incorporating lipophilic herbal extracts or essential oils. Organogels enhance the penetration of lipophilic compounds through the skin and offer controlled release properties (Mehta et al., 2016).

#### C. Emulgel:

Emulgels represent a hybrid formulation combining the advantages of both emulsions and gels. They are suitable for incorporating both hydrophilic and lipophilic herbal extracts within a single formulation. The internal phase (oil or water) can solubilize lipophilic actives, while the continuous phase maintains gel consistency. Common gelling agents used in emulgels include Carbopol and HPMC, while emulsifying agents such as Span 20, Tween 80, or lecithin help stabilize the emulsion system. Emulgels exhibit improved drug release, enhanced skin permeation, and better stability of phytoconstituents compared to conventional gels (Olayemi and David 2023).

### 5.2 Role of Excipients in Gel Formulation

Excipients are the non-active ingredients that play crucial roles in ensuring the functionality, stability, and usability of polyherbal gels. They include neutralizers, humectants, penetration enhancers, preservatives, antioxidants, and stabilizers, each serving a distinct purpose (Tiwari et al., 2024).

#### A. Neutralizers

Neutralizers are essential for adjusting the pH of polymeric gels, especially those formulated with Carbopol. Upon neutralization, the polymer swells to form a clear, viscous gel (Om and Amol 2015). Commonly used neutralizing agents include:

- **Triethanolamine (TEA)**
- **Sodium hydroxide**
- **Potassium hydroxide**

The final pH should be adjusted between 5.5–6.5 to match the physiological pH of the skin, ensuring both stability and user comfort (Lukić et al., 2021).

### B. Humectants and Moisturizers

Humectants maintain hydration of the gel and prevent drying during storage or application. They also contribute to skin softness and enhance penetration of active constituents by maintaining hydration of the stratum corneum (Schafer et al., 2023). Common humectants include:

- Glycerin
- Propylene glycol
- Polyethylene glycol (PEG 400)
- Sorbitol

### C. Penetration Enhancers

To improve the transdermal delivery of phytoconstituents, penetration enhancers are incorporated. They modify the structure of the stratum corneum, increasing its permeability without causing irritation (Herman and Herman 2015). Examples include:

- Ethanol and Isopropanol – act as co-solvents and enhance penetration.
- Oleic acid, Linoleic acid – disrupt lipid bilayers, improving diffusion of active molecules.
- Essential oils (e.g., menthol, eucalyptus oil, turpentine oil) – serve dual roles as fragrance and penetration enhancers. The choice and concentration must be optimized to balance efficacy and safety, as excessive use can lead to irritation (Rana et al., 2025).

### D. Preservatives

Since polyherbal gels contain water and natural ingredients susceptible to microbial contamination, preservatives are crucial for ensuring product safety and shelf life (Teshome et al., 2022). Common preservatives include:

- Methyl paraben and Propyl paraben
- Phenoxyethanol
- Benzyl alcohol
- Sodium benzoate

### E. Antioxidants and Stabilizers

Many herbal extracts contain polyphenolic compounds that are prone to oxidation, leading to degradation and discoloration. Antioxidants prevent oxidative deterioration and maintain chemical stability (Brglez Mojzeret et al., 2016). Examples include:

- Ascorbic acid (Vitamin C)
- Tocopherol (Vitamin E)
- Butylated hydroxytoluene (BHT)
- Butylated hydroxyanisole (BHA).

### F. Fragrances and Colorants (Optional)

Natural essential oils or herbal fragrances can improve consumer acceptability, though they must be used in minimal concentrations to avoid sensitization. Natural colorants such as chlorophyll or curcumin can enhance the appearance of the gel while retaining herbal authenticity (Habib et al., 2024).

#### 5.3 Formulation strategy for multiple extracts

- Decide whether to co-extract or mix standardized extracts.
- pH optimization to preserve stability of most sensitive constituents.
- Address solubility mismatch (use cosolvents, micellar systems, emulgels, or nanoemulsions) (Preeti, Sambhakret et al., 2023).

#### 5.4 Criteria for Selection of Gel Base and Excipients

When formulating a polyherbal gel, the following factors should be carefully considered:

- **Compatibility** between extract components and excipients to prevent precipitation or degradation.
- **Physiological acceptability**, ensuring non-irritancy and pH compatibility with skin.
- **Rheological behavior**, achieving optimum viscosity for easy application and stability.
- **Release kinetics**, ensuring controlled and sustained release of active compounds.
- **Aesthetic properties**, such as smooth texture, clarity, and pleasant odor.
- **Shelf-life stability**, including physical, chemical, and microbial stability under various storage conditions (Man, 2015).

## VI. PREPARATION METHODS (EXAMPLE PROTOCOL)

The formulation of a polyherbal gel involves systematic steps to ensure homogeneity, stability, and reproducible therapeutic efficacy. The process generally includes selection and weighing of ingredients, preparation of the aqueous and extract phases, addition of excipients, neutralization to form the gel matrix, homogenization, deaeration, and packaging. Each step must be carried out with precision to maintain the integrity of phytoconstituents and achieve a stable final product (Lantink and Hörnig 2023).

A general Carbopol-based polyherbal gel preparation involves the following steps:

- **Preparation of Gel Base:** Disperse Carbopol 934 (0.5–1.0% w/w) in distilled water under

constant stirring until uniform; allow to hydrate.

- **Preparation of Extract Phase:** Dissolve the standardized herbal extracts in a suitable solvent system (ethanol:water or propylene glycol). Add humectants and preservatives(Lantink and Hörnig 2023).
- **Combination:** Slowly add the extract phase into the hydrated Carbopol under continuous stirring to ensure even distribution.
- **Neutralization:** Add triethanolamine dropwise to adjust the pH and induce gelation.
- **Homogenization:** Mix thoroughly using a homogenizer to remove lumps and entrapped air.
- **Packaging:** Transfer the prepared gel into sterile, air-tight containers or tubes and store under controlled temperature (Abulfathi, 2017).

## VII. EVALUATION METHODS

The evaluation of a polyherbal gel formulation is a crucial step to ensure its quality, stability, safety, and efficacy. Comprehensive characterization includes physicochemical, chemical, microbiological, biological, and stability studies. Each evaluation parameter provides specific information about the performance and integrity of the gel formulation, ensuring consistency between batches and compliance with pharmacopeial standards (Sharma et al., 2022).

### 7.1 Physicochemical characterization

- **Appearance, color, and homogeneity:** The visual appearance of the gel provides an immediate indication of its uniformity and aesthetic acceptability. A well-formulated polyherbal gel should exhibit: A smooth, uniform texture without lumps or air bubbles. A consistent color characteristic of the incorporated herbal extracts. Absence of phase separation or precipitation. Clarity or translucency, depending on the polymer and extract used(Rodrigues et al., 2015).
- **pH:**The pH of topical gels should be compatible with that of the skin (approximately 5.0–6.5) to avoid irritation (Slavkova et al., 2023).
- **Viscosity and rheology:**Viscosity directly affects spreadability, drug release, and patient acceptability. It is measured using a Brookfield viscometer equipped with appropriate spindle (e.g., spindle No. 63 or 64) at varying rotational speeds (10–100 rpm).

- **Spreadability:**Spreadability determines the ease with which a gel can be applied over the skin surface.
- **Extrudability:**Extrudability reflects the force required to expel the gel from a collapsible tube(Lopez Hernandez et al., 2021).
- **Texture profile analysis:** Instrumental texture analysis provides an objective assessment of parameters such as firmness, cohesiveness, and adhesiveness using a Texture Analyzer. These attributes influence consumer acceptance and application behavior. A gel should be firm enough to retain shape but soft enough to spread easily, with moderate adhesiveness for skin retention(Rathod and Mehta 2015).

### 7.2 Chemical assays

**A. Assay of marker compounds (HPLC/GC):**Quantitative determination of marker phytoconstituents ensures batch-to-batch uniformity and therapeutic consistency(Dayane, 2023).

#### Techniques:

- **High-Performance Liquid Chromatography (HPLC)** for polyphenols, alkaloids, and flavonoids.
  - **Gas Chromatography (GC)** for volatile components and essential oils.
- Parameters evaluated:**
- **% drug content, assay value, and recovery studies** (to check uniform distribution). These data confirm that actives remain stable and evenly dispersed within the gel matrix.
  - **Total Phenolic Content (TPC):** Measured by the Folin-Ciocalteu reagent method, results expressed as mg gallic acid equivalents (GAE)/g of gel.
  - **Total Flavonoid Content (TFC):** Determined using the AlCl<sub>3</sub> colorimetric method, expressed as mg quercetin equivalents (QE)/g. These serve as fingerprint parameters for phytochemical standardization and comparison of different batches(Mushtaque et al., 2023).

### 7.3 Microbiological tests

- **Preservative Efficacy (Challenge Test):** Confirms ability to resist microbial contamination.
- **Microbial Load:** Checks for absence of pathogens like *S. aureus*, *P. aeruginosa*, and *Candida albicans*(Brandenburg et al., 2021).

#### 7.4 In vitro release and permeation

- **In vitro release:** Franz diffusion cell with synthetic membrane (e.g., cellulose acetate) to obtain release kinetics; fit models (zero-order, first-order, Higuchi, Korsmeyer–Peppas).
- **Ex vivo permeation:** Use excised human or animal skin (rat/porcine) in Franz diffusion cells to assess permeation flux, lag time, and skin retention. Quantify marker(s) in receptor fluid and skin layers (Parga et al., 2025).
- **Skin deposition studies:** Tape-strip method to measure epidermal/dermal distribution.

#### 7.5 Biological activity assays

- **Antimicrobial assays:** Agar diffusion and MIC determination for target pathogens.
- **Anti-inflammatory assays:** In vitro inhibition of COX/LOX or cell-based cytokine (TNF- $\alpha$ , IL-6) assays; in vivo models like TPA-induced ear edema.
- **Wound-healing assays:** Scratch assay (in vitro), excisional wound models (in vivo) assessing rate of closure, histology.
- **Antioxidant assays:** DPPH, ABTS, FRAP — useful to compare batches (Shah and Modi 2015).

#### 7.6 Safety and irritation testing

- **In vitro cytotoxicity:** Keratinocyte or fibroblast viability (MTT assay).
- **Skin irritation/allergenicity:** Draize test (animal) or human patch test (ethical approval required).
- **Sensitization:** Local lymph node assay (LLNA) (Pellenzet et al., 2018).

#### 7.7 Stability studies

- **Accelerated stability** (40°C/75% RH) and long-term (25°C/60% RH) per ICH guidelines for semisolids. Monitor physical appearance, pH, viscosity, microbial limits, and marker content over time.
- **Photostability** if extracts are light-sensitive (Kashinath et al., 2024).

### VIII. ADVANTAGES OF POLYHERBAL GEL FORMULATIONS

- Provide synergistic therapeutic effects from multiple herbal actives.
- Offer enhanced skin penetration and sustained release.

- Minimize side effects due to lower individual component doses.
- Easy to apply, non-greasy, and aesthetically pleasing.
- Improved stability and shelf life of sensitive phytoconstituents.
- Suitable for multifunctional applications (antimicrobial, anti-acne, wound-healing, anti-aging) (Bhingee et al., 2017).

### IX. APPLICATIONS OF POLYHERBAL GELS

Polyherbal gels are utilized in several therapeutic and cosmetic applications including:

- Anti-acne and anti-inflammatory formulations
- Wound healing and burn treatment gels
- Antioxidant and anti-aging skin care
- Antifungal and antimicrobial topical treatments
- Pain-relieving herbal liniments (Chellathurai et al., 2023).

### X. CONCLUSION

Polyherbal gel formulations provide an innovative and effective platform for combination therapy using natural plant extracts. By integrating multiple herbs with diverse pharmacological actions, these gels offer enhanced efficacy, safety, and user satisfaction. Their multi-target action, combined with ease of topical delivery and aesthetic acceptability, makes them a valuable alternative to synthetic preparations. Standardization, optimization, and clinical validation remain key to establishing polyherbal gels as reliable therapeutic agents in modern medicine.

### REFERENCES

- [1]. Dev, S. K., Choudhury, P. K., Srivastava, R., & Sharma, M. (2019). Antimicrobial, anti-inflammatory and wound healing activity of polyherbal formulation. *Biomedicine & Pharmacotherapy*, 111, 555-567.
- [2]. Chaachouay, N. (2025). Synergy, additive effects, and antagonism of drugs with plant bioactive compounds. *Drugs and Drug Candidates*, 4(1), 4.
- [3]. Shah, P., Banerjee, S., Singh, A., Kulhari, H., & Anand Saharan, V. (2025). From traditional to modern medicine: the role of herbs and phytoconstituents in pharmaceuticals, nutraceuticals, and cosmetics. *Formulating Pharma-, Nutra-, and Cosmeceutical Products from Herbal*

- Substances: Dosage Forms and Delivery Systems, 3-73.
- [4]. Agrawal, R., Jurel, P., Deshmukh, R., Harwansh, R. K., Garg, A., Kumar, A., ...&Kumarasamy, V. (2024). Emerging trends in the treatment of skin disorders by herbal drugs: traditional and nanotechnological approach. *Pharmaceutics*, 16(7), 869.
- [5]. Matar, D. Y., Ng, B., Darwish, O., Wu, M., Orgill, D. P., & Panayi, A. C. (2023). Skin inflammation with a focus on wound healing. *Advances in Wound Care*, 12(5), 269-287.
- [6]. Chaachouay, N. (2025). Synergy, additive effects, and antagonism of drugs with plant bioactive compounds. *Drugs and Drug Candidates*, 4(1), 4.
- [7]. Zhou, X., Seto, S. W., Chang, D., Kiat, H., Razmovski-Naumovski, V., Chan, K., & Bensoussan, A. (2016). Synergistic effects of Chinese herbal medicine: a comprehensive review of methodology and current research. *Frontiers in pharmacology*, 7, 201.
- [8]. Sulaiman, C. T., Anju, K., Anandan, E. M., & Balachandran, I. (2021). Synergistic interactions of phytochemicals in polyherbal formulation enhance the chemical transformations of active constituents. *Journal of Applied Spectroscopy*, 88(1), 181-186.
- [9]. Gerber, W., Steyn, J. D., Kotzé, A. F., & Hamman, J. H. (2018). Beneficial pharmacokinetic drug interactions: a tool to improve the bioavailability of poorly permeable drugs. *Pharmaceutics*, 10(3), 106.
- [10]. Chaachouay, N. (2025). Synergy, additive effects, and antagonism of drugs with plant bioactive compounds. *Drugs and Drug Candidates*, 4(1), 4.
- [11]. Rahim, T. (2024). Polyherbal formulations in Ayurveda and their relevance in contemporary phytotherapy. *JPP*, 1(1), 13-20.
- [12]. Kroenke, K. (2014). A practical and evidence-based approach to common symptoms: a narrative review. *Annals of internal medicine*, 161(8), 579-586.
- [13]. Balkrishna, A., Sharma, N., Srivastava, D., Kukreti, A., Srivastava, S., & Arya, V. (2024). Exploring the safety, efficacy, and bioactivity of herbal medicines: bridging traditional wisdom and modern science in healthcare. *Future Integrative Medicine*, 3(1), 35-49.
- [14]. Hoang, T. P. N., Ghorri, M. U., & Conway, B. R. (2021). Topical antiseptic formulations for skin and soft tissue infections. *Pharmaceutics*, 13(4), 558.
- [15]. Kalaskar, M., Yele, S. U., Ayyanar, M., Gurav, N., Beldar, V., & Surana, S. J. (2025). Methods of Extraction. *Pharmacognosy and Phytochemistry: Principles, Techniques, and Clinical Applications*, 121-142.
- [16]. Alamgir, A. N. M. (2017). Herbal drugs: their collection, preservation, and preparation; evaluation, quality control, and standardization of herbal drugs. In *Therapeutic Use of Medicinal Plants and Their Extracts: Volume 1: Pharmacognosy* (pp. 453-495). Cham: Springer International Publishing.
- [17]. Izadi, R., Mahinroosta, M., Mohammadzadeh, K., & Ashrafizadeh, S. N. (2023). An inclusive review on inorganic gels: classifications, synthesis methods and applications. *Journal of the Iranian Chemical Society*, 20(8), 1757-1779.
- [18]. Rathod, H. J., & Mehta, D. P. (2015). A review on pharmaceutical gel. *International Journal of Pharmaceutical Sciences*, 1(1), 33-47.
- [19]. Un Nabi, S. A. A., Sheraz, M. A., Ahmed, S., Mustaan, N., & Ahmad, I. (2016). Pharmaceutical gels: a review. *RADS J. Pharm. Pharm. Sci*, 4, 40-48.
- [20]. Kulawik-Pióro, A., & Miastkowska, M. (2021). Polymeric gels and their application in the treatment of psoriasis vulgaris: A review. *International Journal of Molecular Sciences*, 22(10), 5124.
- [21]. Shamlooh, M. S. (2020). Development of Polymeric Crosslinkable Formulations for Conformance Control In Oil and Gas Reservoirs.
- [22]. Romão, S., Bettencourt, A., & Ribeiro, I. A. (2022). Novel features of cellulose-based films as sustainable alternatives for food packaging. *Polymers*, 14(22), 4968.
- [23]. Kamaly, N., Yameen, B., Wu, J., & Farokhzad, O. C. (2016). Degradable controlled-release polymers and polymeric nanoparticles: mechanisms of controlling drug release. *Chemical reviews*, 116(4), 2602-2663.

- [24]. Bora, S., Patel, S., Sharma, S., Pooja, D., &Kulhari, H. (2025). Natural Polysaccharides for Designing Herbal Formulations. Formulating Pharma-, Nutra-, and Cosmeceutical Products from Herbal Substances: Dosage Forms and Delivery Systems, 119-137.
- [25]. Taylor, M. J., Tomlins, P., & Sahota, T. S. (2017). Thermoresponsive gels. *Gels*, 3(1), 4.
- [26]. Usama, S., Riaz, M., Ali, B., Khan, D. S., Ahmad, S., & Ahmad, Z. (2024). Hydrogel-Plant Extract Composites in Wound Healing. *Phytopharmacology Research Journal*, 3(2), 26-29.
- [27]. Mehta, C., Bhatt, G., &Kothiyal, P. (2016). A review on organogel for skin aging. *Indian Journal of Pharmaceutical and Biological Research*, 4(3), 28.
- [28]. Olayemi, O. J., & David, C. (2023). Emulgel: A promising technology for topical delivery of herbal extracts. *British Journal of Pharmacy*, 8(1), 1-13.
- [29]. Tiwari, N., Rai, V., & Singh, S. (2024). A Review on Herbal Excipients in Pharmaceutical Formulations. *IASR Journal of Medical and Pharmaceutical Science*, 4, 18-23.
- [30]. Om, S., & Amol, K. (2015). Carbomer: A Comprehensive Review. *Inventi Rapid: Pharm Tech*, 2016(1), 1-8.
- [31]. Lukić, M., Pantelić, I., &Savić, S. D. (2021). Towards optimal ph of the skin and topical formulations: From the current state of the art to tailored products. *Cosmetics*, 8(3), 69.
- [32]. Schafer, N., Balwierz, R., Biernat, P., Ochędzan-Siodłak, W., &Lipok, J. (2023). Natural ingredients of transdermal drug delivery systems as permeation enhancers of active substances through the stratum corneum. *Molecular Pharmaceutics*, 20(7), 3278-3297.
- [33]. Herman, A., & Herman, A. P. (2015). Essential oils and their constituents as skin penetration enhancer for transdermal drug delivery: a review. *Journal of Pharmacy and Pharmacology*, 67(4), 473-485.
- [34]. Rana, P., Pathania, D., Gaur, P., Patel, S. K., Bajpai, M., Singh, N. T., & Dwivedi, A. (2025). Regulatory frameworks for fragrance safety in cosmetics: a global overview. *Toxicological Research*, 1-22.
- [35]. Teshome, E., Forsido, S. F., Rupasinghe, H. V., &OlikaKeyata, E. (2022). Potentials of natural preservatives to enhance food safety and shelf life: A review. *The Scientific World Journal*, 2022(1), 9901018.
- [36]. BrglezMojzer, E., KnezHrnčič, M., Škerget, M., Knez, Ž.,& Bren, U. (2016). Polyphenols: Extraction methods, antioxidative action, bioavailability and anticarcinogenic effects. *Molecules*, 21(7), 901.
- [37]. Habib, N., Batool, F., Adeel, S., Naveed, M., Ali, A., Mia, R., &Assiri, M. A. (2024). Green extraction and application of yellow natural curcumin colorant from *Curcuma aromatica* rhizomes for silk dyeing. *Sci*
- [38]. Preeti, Sambhakar, S., Malik, R., Bhatia, S., Al Harrasi, A., Rani, C., &Sehrawat, R. (2023). Nanoemulsion: an emerging novel technology for improving the bioavailability of drugs. *Scientifica*, 2023(1), 6640103.
- [39]. Man, D. (2015). Shelf life. John Wiley & Sons.
- [40]. Lantink, R., &Hörnig, M. (2023). Raw Materials. In *Practical Pharmaceutics: An International Guideline for the Preparation, Care and Use of Medicinal Products* (pp. 127-167). Cham: Springer International Publishing.
- [41]. Lantink, R., &Hörnig, M. (2023). Raw Materials. In *Practical Pharmaceutics: An International Guideline for the Preparation, Care and Use of Medicinal Products* (pp. 127-167). Cham: Springer International Publishing.
- [42]. Abulfathi, F. A. (2017). Evaluation and validation of room temperature biospecimens transportation and storage technologies as an alternative cost effective solution to cold chain logistics and storage within biobanking and/or diagnostics (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- [43]. Sharma, U., Arjariya, S., Chouksey, R., & Sharma, N. (2022). A Review: Formulation and Evaluation of Pharmaceutical Gel. *Journal of Pharmaceutical Negative Results*, 13.
- [44]. Rodrigues, R. A., Yamane, L. T., & de Freitas, V. S. (2015). How to improve some properties and qualities of plant extracts and their derivatives using

- pharmacotechnical technology approach. Therapeutic Medicinal Plants: From Lab to the Market, 197-216.
- [45]. Slavkova, M., Tzankov, B., Popova, T., & Voycheva, C. (2023). Gel formulations for topical treatment of skin cancer: A review. *Gels*, 9(5), 352.
- [46]. Lopez Hernandez, H., Souza, J. W., & Appel, E. A. (2021). A quantitative description for designing the extrudability of shear-thinning physical hydrogels. *Macromolecular Bioscience*, 21(2), 2000295.
- [47]. Rathod, H. J., & Mehta, D. P. (2015). A review on pharmaceutical gel. *International Journal of Pharmaceutical Sciences*, 1(1), 33-47.
- [48]. Dayane, S. (2023). Can advanced analytical techniques ensure consistent quality in herbal medicines?. *Innovations in Pharmacy Planet*, 53-57.
- [49]. Mushtaque, M., Rahman, M. A., Khan, I., & Haque, A. (2023). Chromatographic Techniques in Phytochemistry and Analytical Techniques in Elemental Profiling. In *Ethnobotany and Ethnopharmacology of Medicinal and Aromatic Plants: Steps Towards Drug Discovery: Steps Towards Drug Discovery* (pp. 257-271). CRC Press.
- [50]. Brandenburg, K. S., Weaver Jr, A. J., Karna, S. R., & Leung, K. P. (2021). The impact of simultaneous inoculation of *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and *Candida albicans* on rodent burn wounds. *Burns*, 47(8), 1818-1832.
- [51]. Parga, A. D., Doshi, N., Bhat, R. M., Vu, T., Sraa, K., Casagrande, S., & Vu, T. N. (2025). Transdermal Drug Delivery Systems in Atopic Dermatitis: A Review of Vehicle Innovation and Skin Barrier Challenges. *Cureus*, 17(10).
- [52]. Shah, P., & Modi, H. A. (2015). Comparative study of DPPH, ABTS and FRAP assays for determination of antioxidant activity. *Int. J. Res. Appl. Sci. Eng. Technol*, 3(6), 636-641.
- [53]. Pellenz, N. L., Barbisan, F., Azzolin, V. F., Duarte, T., Bolognon, A., Mastella, M. H., & Duarte, M. M. (2018). Analysis of In Vitro Cyto-and Genotoxicity of Barbatimão Extract on Human Keratinocytes and Fibroblasts. *BioMed research international*, 2018(1), 1942451.
- [54]. Kashinath, K. P., Sardar, M. S., Sah, S. K., & Kaity, S. (2024). Stability and accelerated stability studies of dosage forms. In *Physico-Chemical Aspects of Dosage Forms and Biopharmaceutics* (pp. 19-42). Academic Press.
- [55]. Bhinge, S. D., Bhutkar, M. A., Randive, D. S., Wadkar, G. H., Todkar, S. S., Kakade, P. M., & Kadam, P. M. (2017, September). Formulation development and evaluation of antimicrobial polyherbal gel. In *Annalespharmaceutiquesfrançaises* (Vo l. 75, No. 5, pp. 349-358). Elsevier Masson.
- [56]. Chellathurai, B. J., Anburose, R., Alyami, M. H., Sellappan, M., Bayan, M. F., Chandrasekaran, B., & Rahamathulla, M. (2023). Development of a polyherbal topical gel for the treatment of acne. *Gels*, 9(2), 163.