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Review Article

Nanoemulsion-Based Polyherbal Formulations for Acne Vulgaris: Formulation Approaches, Characterisation and Therapeutic Potential

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Abstract

Acne vulgaris is a long-standing inflammatory disorder of the pilosebaceous unit that predominantly affects adolescents and young adults and often persists into adulthood. The condition develops due to the combined influence of abnormal follicular keratinisation, excessive sebum secretion, microbial proliferation, and immune-mediated inflammation. Conventional therapies such as topical antibiotics, retinoids, and benzoyl peroxide are widely used; however, their long-term application is associated with adverse effects including skin irritation, erythema, photosensitivity, teratogenicity, and the emergence of antibiotic resistance. These limitations have intensified the search for safer and more effective therapeutic alternatives. Herbal medicines have gained increasing attention due to their antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties, as well as their better patient tolerability. Despite their therapeutic potential, many herbal actives exhibit poor solubility, instability, and limited skin penetration, thereby limiting their clinical efficacy. Nanoemulsion technology has emerged as a promising topical drug delivery system that enhances the solubility, stability, and dermal penetration of phytoconstituents. Polyherbal nanoemulsion formulations, which combine multiple herbal actives, offer synergistic and multi-targeted therapeutic effects against acne pathogenesis. This review critically summarizes the current status of nanoemulsion-based polyherbal formulations for the management of acne vulgaris, with emphasis on key herbal actives such as garlic oil and Manuka honey, along with other supportive botanicals. Formulation strategies, characterization techniques, biological evaluation approaches, challenges, and future perspectives are comprehensively discussed. This review highlights recent advances in nanoemulsion-based polyherbal formulations and emphasizes their potential as safer and effective topical alternatives for acne management.

Keywords: Acne vulgaris, Polyherbal formulation, Nanoemulsion, Garlic oil, Manuka honey, Topical drug delivery

1. Introduction

Acne vulgaris is one of the most common dermatological conditions worldwide, with significant clinical and psychosocial effects across diverse age groups. It primarily affects adolescents, although its persistence into adulthood is increasingly reported[1, 4]. Clinically, acne is characterized by non-inflammatory lesions such as open and closed comedones, and inflammatory lesions including papules, pustules, nodules, and cysts. Beyond its physical manifestations, acne has a profound psychosocial impact, often leading to diminished self-esteem, anxiety, depression, and reduced quality of life[2, 4].

The pathogenesis of acne is multifactorial and is associated with four interrelated mechanisms: follicular hyperkeratinization, excessive sebum production, colonization of pilosebaceous units by Cutibacterium acnes, and inflammation[3, 5]. Conventional acne therapies target one or more of these mechanisms. Topical retinoids normalize keratinization, antibiotics reduce microbial load, and benzoyl peroxide acts as a potent antimicrobial and keratolytic agent. Systemic therapies, including oral antibiotics and isotretinoin, are prescribed in moderate to severe cases.

Despite their clinical effectiveness, conventional therapies present several limitations. Prolonged use of topical antibiotics contributes to the development of antibiotic-resistant strains of Cutibacterium acnes and other commensal skin bacteria. Retinoids and benzoyl peroxide are frequently associated with local adverse effects such as erythema, dryness, peeling, burning sensation, and photosensitivity, leading to poor patient compliance. Systemic retinoids carry significant risks, including teratogenicity, hepatotoxicity, and lipid abnormalities[6]. These drawbacks underscore the urgent need for alternative therapeutic strategies that are effective, safe, and suitable for long-term use.

In recent years, herbal and natural products have gained substantial attention in dermatology due to their broad spectrum of biological activities and favourable safety profiles. Numerous medicinal plants and natural substances exhibit antimicrobial, anti-inflammatory,

antioxidant, and wound-healing properties relevant to acne management[12, 13]. Garlic oil, rich in organosulfur compounds, demonstrates potent antibacterial activity against acne-associated microorganisms. Manuka honey, characterized by high methylglyoxal content, possesses strong antimicrobial and anti-inflammatory effects along with excellent wound-healing properties. Other botanicals such as tea tree oil, neem, turmeric, green tea, and aloe vera have also been extensively studied for their anti-acne potential.

However, the therapeutic application of herbal actives is often limited by poor aqueous solubility, chemical instability, volatility, unpleasant odor, and inadequate skin penetration. These limitations reduce bioavailability and therapeutic effectiveness when herbal actives are incorporated into conventional topical dosage forms[10]. Advanced drug delivery systems are therefore required to overcome these challenges.

Nanoemulsion technology has emerged as a promising approach for the topical delivery of herbal actives. Nanoemulsions represent finely dispersed oil-water systems in which nanoscale droplets facilitate enhanced solubilisation, stability, and dermal transport of lipophilic bioactives.Due to their small droplet size and large surface area, nanoemulsions enhance the solubilization of lipophilic compounds, improve skin penetration, and provide controlled release of active ingredients[7,9,11,31,32]. When incorporated into cream or gel bases, nanoemulsions offer improved cosmetic acceptability and patient compliance.

The concept of polyherbal formulation is deeply rooted in traditional medicine systems, where combinations of herbs are used to achieve synergistic therapeutic effects. Polyherbal nanoemulsion systems combine the advantages of herbal synergy with nanotechnology, enabling simultaneous targeting of multiple pathogenic factors involved in acne vulgaris. Such systems have the potential to offer superior efficacy compared to single-herb formulations while minimizing adverse effects[11, 12].

This review aims to provide a comprehensive and critical evaluation of nanoemulsion-based polyherbal formulations for acne vulgaris. It discusses the pathophysiology of acne, the therapeutic potential of key herbal actives, nanoemulsion formulation strategies, characterization techniques, biological evaluation methods, challenges in development, and future research directions. The review seeks to bridge existing knowledge gaps and highlight the translational potential of polyherbal nanoemulsion creams as next-generation anti-acne therapies.

2. Novelty and Unique Contribution of the Review

The present review provides a focused and integrated discussion on nanoemulsion-based polyherbal formulations for the management of acne vulgaris, an area that has not been comprehensively addressed in existing literature. Unlike earlier reviews that examine nano-delivery systems or herbal anti-acne therapies as separate entities, this article uniquely combines polyherbal therapeutic principles with nanoemulsion-based topical delivery, offering a unified perspective on their potential in acne management.

A key novel aspect of this review is its specific emphasis on garlic oil and Manuka honey as principal bioactive components, along with supportive herbal ingredients, highlighting their complementary antimicrobial, anti-inflammatory, antioxidant, and wound-healing properties when delivered through nanoemulsion systems. The review systematically correlates formulation approaches, physicochemical characterization, and biological evaluation parameters, thereby providing a coherent framework for the rational development of polyherbal nanoemulsion creams.

By critically analysing formulation strategies, therapeutic mechanisms, and existing challenges, this review contributes meaningful insight into the design and development of safe and effective polyherbal nanoemulsion-based topical therapies for acne vulgaris.

3. Pathophysiology of Acne Vulgaris

Acne vulgaris develops as a result of a complex interaction between hormonal, microbial, and immunological factors that primarily affect the pilosebaceous unit. The initial pathological event involves altered follicular keratinization, which leads to narrowing and obstruction of the follicular canal. This process promotes the accumulation of corneocytes and sebum within the follicle, creating an environment conducive to lesion formation. Androgen-mediated stimulation of sebaceous glands results in increased sebum production, particularly during adolescence. Excess sebum not only contributes to follicular blockage but also serves as a nutrient source for resident skin microorganisms. Among these, Cutibacterium acnes plays a crucial role in disease progression by colonizing lipid-rich follicles and producing lipolytic enzymes that degrade sebum triglycerides into pro-inflammatory free fatty acids. The presence of Cutibacterium acnes within the follicle triggers activation of innate immune pathways, including toll-like receptor signaling on keratinocytes and immune cells. This activation promotes the release of inflammatory mediators such as interleukins and tumor necrosis factor, which further amplify local inflammation[23, 30]. The inflammatory response contributes to follicular wall rupture and the spread of inflammatory contents into surrounding dermal tissue, leading to the formation of papules, pustules, and nodules[3, 5].

Collectively, the interplay between follicular obstruction, sebaceous hyperactivity, microbial proliferation, and immune activation drives the clinical manifestations of acne vulgaris and underlines the need for therapeutic strategies that target multiple pathogenic pathways simultaneously.

4. Herbal Actives Used in the Management of Acne Vulgaris

Herbal medicines have long been used in the treatment of skin disorders due to their wide spectrum of biological activities and relatively low incidence of

adverse effects[12]. In acne vulgaris, herbal actives are particularly valuable because they can simultaneously exert antimicrobial, anti-inflammatory, antioxidant, and wound-healing effects. This multi-targeted action aligns well with the multifactorial pathogenesis of acne. In recent years, several herbal actives have been incorporated into nanoemulsion-based topical formulations to enhance their stability, penetration, and therapeutic efficacy.

4.1 Garlic Oil (Allium sativum L.)

Garlic oil is obtained from the bulbs of Allium sativum and is rich in organosulfur compounds such as allicin, ajoene, diallyl disulfide, and diallyl trisulfide. These compounds are responsible for garlic's characteristic odour as well as its potent pharmacological properties.

Garlic oil is well recognised for its broad antimicrobial potential, which is primarily attributed to sulphur-containing phytoconstituents that interfere with essential enzymatic processes in microbial cells. The antibacterial action is attributed to the interaction of organosulfur compounds with thiol-containing enzymes in microbial cells, leading to inhibition of essential metabolic pathways. In addition to its antimicrobial activity, garlic oil possesses anti-inflammatory properties by modulating inflammatory mediators such as prostaglandins and cytokines. It also exhibits antioxidant activity, which helps reduce oxidative stress involved in acne pathogenesis[14, 16, 35].

Despite its therapeutic potential, the topical application of garlic oil is limited by its volatility, strong odour, chemical instability, and potential for skin irritation at higher concentrations. Nanoemulsion-based delivery systems help overcome these limitations by encapsulating garlic oil within nanosized droplets, thereby improving stability, masking odour, enhancing skin penetration, and enabling controlled release.

4.2 Manuka Honey (Leptospermum scoparium)

Manuka honey is a monofloral honey produced from the nectar of Leptospermum scoparium, native to New Zealand. It is distinguished from other types of honey by its high content of methylglyoxal (MGO) and Unique Manuka Factor (UMF), which are responsible for its potent antibacterial activity.

Manuka honey demonstrates pronounced antibacterial activity through multiple mechanisms, including osmotic effects, acidic pH, and the presence of bioactive compounds such as methylglyoxal[17, 18, 36]. Unlike conventional antibiotics, honey exerts its antibacterial action through multiple mechanisms, including osmotic effects, low pH, hydrogen peroxide production, and the presence of bioactive compounds such as MGO. Importantly, bacterial resistance to honey has not been reported, making it an attractive option for long-term acne management.

In addition to its antimicrobial properties, Manuka honey demonstrates significant anti-inflammatory and wound-healing activity[19, 20]. It reduces inflammation by down regulating pro-inflammatory cytokines and promotes tissue repair through enhanced epithelialization and collagen synthesis. These properties are particularly beneficial in acne, where inflammation and post-inflammatory lesions can lead to scarring.

When incorporated into topical formulations, Manuka honey also acts as a natural humectant, improving skin hydration and barrier function. In nanoemulsion-based creams, Manuka honey can be incorporated into the aqueous phase or used in combination with oil-based actives to achieve synergistic therapeutic effects.

4.3 Tea Tree Oil (Melaleuca alternifolia)

Tea tree oil is one of the most extensively studied essential oils for acne management. Its primary active component, terpinen-4-ol, exhibits strong antimicrobial and anti-inflammatory properties. Tea tree oil has been shown to reduce acne lesion count and severity, with efficacy comparable to benzoyl peroxide but with fewer side effects[21, 22].

However, tea tree oil may cause skin irritation or sensitization when used in high concentrations. Nanoemulsion formulations help reduce these adverse effects by improving dispersion, reducing direct contact of concentrated oil with the skin, and enabling controlled release. Antioxidant-rich herbal components help to reduce oxidative stress, which plays a significant role in acne-related inflammation[24].

4.4 Neem (Azadirachta indica)

Neem has a long history of use in traditional medicine systems for treating skin disorders. It contains bioactive compounds such as azadirachtin, nimbidin, quercetin, and nimbin, which contribute to its antimicrobial, anti-inflammatory, and antioxidant properties.

Neem extracts and oils have demonstrated effectiveness against acne-causing bacteria and are known to reduce redness, swelling, and irritation. Neem-based nanoemulsions have been shown to improve skin penetration and stability compared to conventional formulations.

4.5 Turmeric (Curcuma longa)

Turmeric is rich in curcuminoids, particularly curcumin, which possesses potent anti-inflammatory and antioxidant activity. Curcumin inhibits nuclear factor-kappa B (NF-κB) signaling and downregulates pro-inflammatory cytokines involved in acne pathogenesis. It also exhibits antibacterial activity and promotes wound healing.

The poor aqueous solubility and instability of curcumin limit its topical application. Nanoemulsion systems significantly enhance the solubility, stability, and bioavailability of curcumin, making it a promising candidate for anti-acne formulations.

4.6 Green Tea Extract (Camellia sinensis)

Green tea extract is rich in polyphenols, particularly epigallocatechin gallate (EGCG), which exhibits antioxidant, anti-inflammatory, and sebum-regulating effects. EGCG has been shown to inhibit C. acnes growth

and reduce sebum production by modulating androgen activity in sebaceous glands.

Green tea-based nanoemulsions enhance the stability of polyphenols and improve skin penetration, thereby increasing their therapeutic effectiveness in acne management.

4.7 Aloe Vera (Aloe barbadensis Miller)

Aloe vera is widely used in dermatological formulations due to its soothing, moisturizing, and wound-healing properties. It contains polysaccharides, vitamins, enzymes, and amino acids that contribute to its anti-inflammatory and skin-repair effects.

In acne formulations, aloe vera helps reduce irritation, redness, and dryness associated with active antimicrobial agents. It is often used as a supportive component in polyherbal formulations to enhance skin tolerability.

Table 1: Herbal Actives Commonly Used in Nanoemulsion-Based Anti-Acne Formulations

Herbal active	Major constituents	Primary activity
Garlic oil	Allicin, ajoene	Antibacterial, anti-inflammatory
Manuka honey	Methylglyoxal, phenolics	Antibacterial, wound healing
Tea tree oil	Terpinen-4-ol	Antimicrobial
Neem	Azadirachtin	Antibacterial, antioxidant
Turmeric	Curcumin	Anti-inflammatory, antioxidant
Green tea	Epigallocatechin gallate	Sebum regulation, antioxidant
Aloe vera	Polysaccharides	Soothing, wound healing

5. Polyherbal Concept and Scientific Rationale

Polyherbal formulations are designed to integrate multiple botanicals with complementary biological actions, enabling broader therapeutic coverage of complex disease pathways such as acne vulgaris[12, 13, 34]. In acne vulgaris, where multiple pathogenic factors operate simultaneously, a polyherbal approach is particularly advantageous.

Polyherbal nanoemulsion systems can target different aspects of acne pathogenesis, including bacterial proliferation, inflammation, oxidative stress, and impaired wound healing[30]. For example, garlic oil provides strong antibacterial activity, Manuka honey enhances antimicrobial action while promoting healing, turmeric reduces inflammation, and aloe vera improves skin hydration and tolerability. The synergistic interaction among these components results in enhanced efficacy and reduced likelihood of adverse effects.

Moreover, nanoemulsion technology ensures uniform distribution of multiple herbal actives, improved penetration into the pilosebaceous unit, and controlled release at the target site. This combination of herbal synergy and nanotechnology represents a rational and innovative strategy for acne management.

6. Nanoemulsion Technology for Topical Delivery of Herbal Actives

Nanoemulsions are finely dispersed biphasic delivery systems characterised by nanoscale droplets that enhance the solubility, stability, and skin penetration of lipophilic bioactive compounds.[7,8].Due to their small droplet size and large interfacial surface area, nanoemulsions exhibit unique physicochemical properties that make them particularly suitable for topical and transdermal drug delivery[9,10,31,37].

In dermatological applications, nanoemulsions offer several advantages over conventional emulsions and other nanocarrier systems. These include enhanced solubilization of lipophilic compounds, improved skin penetration, increased physical stability, optical transparency, and superior aesthetic appeal. Nanoemulsions can penetrate through the stratum corneum and preferentially accumulate in hair follicles and sebaceous glands, which are the primary sites involved in acne vulgaris.

The ability of nanoemulsions to improve the delivery of herbal actives has been widely documented. Many phytoconstituents, such as essential oils and polyphenols, suffer from poor water solubility and limited bioavailability when applied topically. Nanoemulsion systems overcome these limitations by encapsulating lipophilic actives within nanosized droplets, thereby enhancing their dispersion, stability, and interaction with the skin.

Recent studies have demonstrated the effectiveness of nanoemulsion based systems in improving the therapeutic performance of topical anti-acne formulations.[11].

7. Components of Nanoemulsion Systems

7.1 Oil Phase

The oil phase plays a crucial role in determining the solubilization capacity and therapeutic performance of the nanoemulsion. In anti-acne formulations, essential oils such as garlic oil, tea tree oil, and neem oil serve both as the oil phase and as active antimicrobial agents.

The selection of oil depends on solubility of the active compound, therapeutic relevance, and skin compatibility. Garlic oil, due to its potent antimicrobial activity, is a promising oil phase for acne formulations. However, its volatility and strong odour necessitate incorporation into a nanoemulsion system to improve stability and patient acceptability.

7.2 Surfactants and Co-surfactants

Surfactants reduce interfacial tension between oil and water phases, enabling the formation of stable nano-sized droplets. Non-ionic surfactants such as polysorbates (Tween 20, Tween 80) are commonly preferred for topical nanoemulsions due to their low toxicity, skin compatibility, and ability to form stable emulsions over a wide pH range.

Co-surfactants such as polyethylene glycol (PEG 400), propylene glycol, ethanol, or glycerol are often used in combination with surfactants to further reduce interfacial tension and increase the flexibility of the interfacial film. The ratio of surfactant to co-surfactant (Smix) is a critical parameter that influences nanoemulsion formation, droplet size, and stability.

7.3 Aqueous Phase

The aqueous phase typically consists of purified water or buffered solutions. Hydrophilic actives such as Manuka honey and aloe vera extract can be incorporated into this phase. In polyherbal nanoemulsion creams, the aqueous phase also contributes to skin hydration and improves formulation spreadability.

8. Formulation Strategies for Polyherbal Nanoemulsion Creams

8.1 Construction of Pseudo-Ternary Phase Diagrams

Pseudo-ternary phase diagrams are widely used to identify the concentration ranges of oil, surfactant,co-surfactant, and aqueous phases that result in nanoemulsion formation. These diagrams help in selecting optimal formulation compositions that yield stable nanoemulsions with minimal energy input[11, 33].

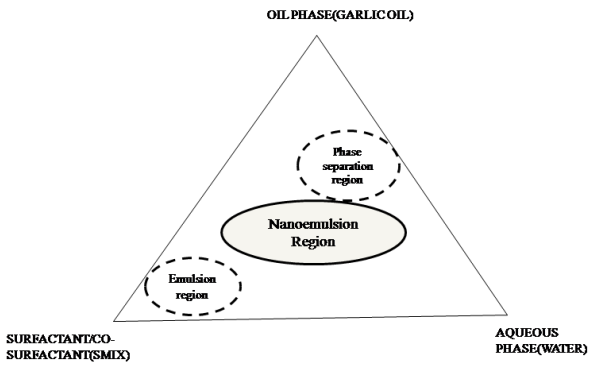

Figure 1: Pseudo-ternary phase diagram showing nanoemulsion, emulsion, and phase separation regions as a function of oil, surfactant/co-surfactant mixture, and aqueous phase composition (Created by authors).

8.2 Methods of Nanoemulsion Preparation

Nanoemulsions can be prepared using low-energy or high-energy methods.

Low-energy methods include spontaneous emulsification and phase inversion temperature techniques, which rely on changes in composition or temperature to induce nanoemulsion formation.

High-energy methods include ultrasonication and high-pressure homogenization, which apply mechanical energy to reduce droplet size. Ultrasonication is widely used at laboratory scale due to its simplicity and effectiveness in producing uniform nanoemulsions.

8.3 Conversion into Nanoemulsion Cream

For improved patient compliance and ease of application, nanoemulsions are often incorporated into semisolid bases to form nanoemulsion creams. Cream bases typically consist of emulsifying waxes, fatty alcohols, and stabilizers that provide suitable viscosity, spreadability, and skin feel. Incorporation of nanoemulsions into cream matrices enhances retention at the application site and reduces runoff.

9. Characterization of Polyherbal Nanoemulsion Systems

Systematic physicochemical evaluation is necessary to confirm the stability, consistency, and functional performance of nanoemulsion-based topical systems. Critical characterization parameters include droplet size, polydispersity index, zeta potential, pH, viscosity, and spreadability, which collectively influence stability and performance[8, 9, 33, 38].

9.1 Droplet Size and Polydispersity Index (PDI)

The physiochemical evaluation of nanoemulsion systems commonly involves assessment of droplet size distribution and uniformity using light-scattering analytical techniques. Smaller droplet sizes enhance skin penetration and stability. A Polydispersity Index value below 0.3 indicates a uniform droplet size distribution and good physical stability.

9.2 Zeta Potential

Zeta potential reflects the surface charge of nanoemulsion droplets and provides insight into formulation stability. Although non-ionic surfactant-based nanoemulsions may exhibit low zeta potential values, steric stabilization often ensures adequate stability.

9.3 pH, Viscosity, and Spreadability

The pH of topical nanoemulsion creams should be compatible with skin physiology, typically in the range of 5.0–6.5. Viscosity and spreadability influence application behaviour and patient acceptance.

9.4 Morphological Evaluation

Transmission electron microscopy (TEM) or scanning electron microscopy (SEM) is used to visualize droplet morphology and confirm nanoscale size and spherical shape.

9.5 In Vitro Drug Release and Permeation Studies

Franz diffusion cells are commonly employed to study drug release and skin permeation profiles of nanoemulsion formulations. These studies provide insight into release kinetics and penetration behaviour of herbal actives[25].

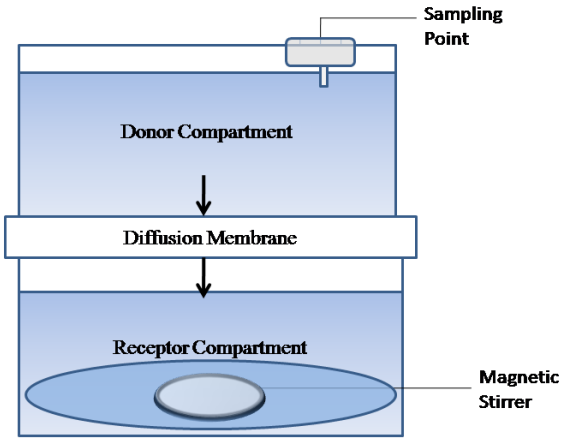

Figure 2: Schematic representation of a Franz diffusion cell used for in vitro permeation studies (Created by authors).

9.6 Stability Studies

Stability studies involve subjecting formulations to different storage conditions, including varying temperature and humidity, as well as centrifugation and freeze–thaw cycles, to evaluate physical and chemical stability[26].

Table 2: Key Characterization Parameters for Nanoemulsion Creams

Parameter	Significance
Droplet size	Influences penetration and stability
PDI	Indicates uniformity of droplets
Zeta potential	Predicts physical stability
pH	Skin compatibility
Viscosity	Spreadability and retention
Stability studies	Shelf-life prediction

10. Biological Evaluation of Polyherbal Nanoemulsion-Based Anti-Acne Formulations

Assessment of biological activity provides experimental support for the therapeutic relevance of nanoemulsion-based polyherbal formulations in acne management. These evaluations aim to confirm antimicrobial efficacy, antioxidant potential, anti-inflammatory effects, skin compatibility, and overall safety.

10.1 Antibacterial Activity

Antibacterial activity is commonly assessed against acne-associated microorganisms, primarily Cutibacterium acnes and Staphylococcus aureus. In vitro antibacterial studies are typically performed using agar well diffusion, disc diffusion, or broth microdilution methods to determine zones of inhibition and minimum inhibitory concentrations (MICs) [15, 17].

Nanoemulsion-based formulations often demonstrate enhanced antibacterial activity compared to conventional formulations due to improved penetration and increased contact between the active compounds and bacterial cell membranes. Garlic oil nanoemulsions have shown strong inhibitory effects on Gram-positive bacteria by disrupting thiol-containing enzymes, while Manuka honey contributes additional antibacterial action through methylglyoxal and osmotic effects. The polyherbal combination further broadens the antibacterial spectrum and reduces the likelihood of resistance development[31, 39].

10.2 Antioxidant Activity

Oxidative stress plays a significant role in acne pathogenesis by promoting inflammation and tissue damage. Antioxidant activity of nanoemulsion formulations is commonly evaluated using free radical scavenging assays such as DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2′-azinobis-(3-ethylbenzothiazoline-6-sulfonic acid)) assays[24].

Polyherbal nanoemulsions containing garlic oil, Manuka honey, turmeric, and green tea extracts have demonstrated strong radical scavenging activity, indicating their potential to neutralize reactive oxygen species and reduce oxidative damage in acne lesions.

10.3 Anti-Inflammatory Activity

Anti-inflammatory activity is assessed by measuring the inhibition of pro-inflammatory mediators such as nitric oxide, prostaglandins, and cytokines in in vitro or in vivo models. Herbal actives such as garlic oil and turmeric are known to downregulate inflammatory pathways, while Manuka honey helps reduce erythema and accelerate healing of inflamed skin.

10.4 Skin Irritation and Safety Studies

Skin irritation and safety studies are essential for topical formulations. These studies may include patch tests, Draize tests, or in vitro skin irritation models[27]. Nanoemulsion-based creams generally exhibit improved tolerability compared to conventional formulations due to controlled release and reduced concentration of free irritants.

11. Review of Published Nanoemulsion-Based Anti-Acne Studies

A growing number of studies support the use of nanoemulsion systems for topical anti-acne therapy. Herbal nanoemulsions containing tea tree oil, neem oil, curcumin, and garlic oil have shown superior antimicrobial and anti-inflammatory activity compared to conventional creams and gels. Polyherbal nanoemulsions, in particular, demonstrate synergistic effects by targeting multiple pathogenic mechanisms of acne simultaneously.

Clinical studies on herbal nanoemulsions remain limited; however, existing preclinical evidence strongly supports their potential efficacy and safety. The

incorporation of nanoemulsions into cream bases further enhances patient compliance and cosmetic acceptability.

12. Challenges and Limitations

Despite promising results, several challenges hinder the widespread adoption of polyherbal nanoemulsion-based anti-acne formulations[26, 28, 29]:

- Standardization of herbal raw materials: Variability in phytochemical composition due to geographical and seasonal factors.
- Stability concerns: Volatility and degradation of essential oils and bioactive compounds.
- Surfactant-related toxicity: Potential skin irritation at higher surfactant concentrations.
- Regulatory ambiguity: Lack of clear guidelines for herbal nanoformulations.
- Limited clinical data: Insufficient large-scale human trials to confirm efficacy and safety.

Addressing these challenges is essential for successful translation from laboratory research to commercial products[32].

13. Future Perspectives

Future research on polyherbal nanoemulsion formulations for acne vulgaris should focus on:

- Development of standardized herbal extracts with validated biomarkers.
- Use of green and biodegradable surfactants to improve safety.
- Advanced targeting strategies to enhance follicular delivery.
- Long-term stability and shelf-life studies.
- Well-designed clinical trials to establish therapeutic efficacy.
- Regulatory harmonization to facilitate commercialization.

The integration of nanotechnology with traditional herbal medicine holds significant promise for the development of safe, effective, and patient-friendly anti-acne therapies[11].

14. Conclusion

The findings discussed in this review indicate that nanoemulsion-based polyherbal topical formulations offer a promising therapeutic approach for the management of acne vulgaris by addressing multiple pathogenic mechanisms simultaneously. The incorporation of bioactive herbal constituents such as garlic oil and Manuka honey within a nanoemulsion system enhances their stability, skin penetration, and biological efficacy while minimizing the limitations associated with conventional topical therapies.

Nanoemulsion technology provides distinct formulation advantages, including improved solubilization of lipophilic compounds, uniform drug distribution, and enhanced interaction with the skin barrier. These properties contribute to superior antimicrobial and anti-inflammatory performance, which is particularly relevant in the management of acne-associated microbial proliferation and inflammatory responses.

Despite the encouraging outcomes highlighted in existing studies, further investigations focusing on long-term safety, formulation optimization, and clinical validation are warranted. Overall, existing evidence supports the continued exploration of polyherbal nanoemulsion creams as integrative topical platforms, although robust clinical validation remains essential [31, 36].

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