



IJPPR

INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals

ISSN 2349-7203



Human Journals

Review Article

August 2023 Vol.:28, Issue:1

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Herbal Oils Bearing Nanoemulgel for Anti-Inflammatory Action



IJPPR
INTERNATIONAL JOURNAL OF PHARMACY & PHARMACEUTICAL RESEARCH
An official Publication of Human Journals

ISSN 2349-7203



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Submitted: 25 July 2023
Accepted: 18 August 2023
Published: 30 August 2023

Keywords: Nanoemulgel, Herbal oil, Anti-inflammatory, Inflammation, Nanoemulsion and Hydrogel.

ABSTRACT

Nanoemulgel-infused herbal oils have garnered significant attention due to their potential anti-inflammatory effects. This review article provides an overview of the emerging field of nanoemulgel-based formulations for harnessing the anti-inflammatory properties of herbal oils. Nanoemulgel combines the advantages of both nanoemulsion and hydrogel technologies, offering enhanced stability, bioavailability, and prolonged drug release. The article summarizes recent advancements in the preparation and characterization of nanoemulgel-infused herbal oils, highlighting their potential to mitigate inflammation-related disorders. Additionally, the review discusses the mechanisms underlying the anti-inflammatory effects of these formulations, shedding light on the molecular pathways and cellular responses involved. The inclusion of tables and graphs further illustrates the key studies and outcomes in the field. This comprehensive analysis underscores the promising prospects of nanoemulgel-infused herbal oils as a novel therapeutic approach for managing inflammation, thereby paving the way for future research and clinical applications.



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INTRODUCTION

Inflammation, a complex biological response to harmful stimuli, plays a pivotal role in various chronic diseases. Inflammation is a complex physiological response to infections or tissue damage, involving the recruitment of immune cells and various molecular interactions. Proinflammatory cytokines and mediators like IL-1 β , TNF- α , IL-6, nitric oxide (NO), and prostaglandins (PGs) play crucial roles in this process. These molecules are associated with inflammation-related diseases, and inhibitors targeting them are used in treating autoimmune disorders.[1] Cyclooxygenases (COX), particularly COX-2, are enzymes responsible for producing inflammatory PGs. Inhibiting these enzymes has been a therapeutic strategy for managing inflammation. Herbal oils, derived from plant sources, have been recognized for their potential anti-inflammatory properties due to the presence of bioactive compounds. Nanoemulgel, a combination of nanotechnology and hydrogel technology, has emerged as an innovative approach to enhance the therapeutic potential of herbal oils. Nanoemulgel-infused herbal oils have garnered significant attention due to their potential anti-inflammatory effects. This review article provides an overview of the emerging field of nanoemulgel-based formulations for harnessing the anti-inflammatory properties of herbal oils.[2] Nanoemulgel combines the advantages of both nanoemulsion and hydrogel technologies, offering enhanced stability, bioavailability, and prolonged drug release. The article summarizes recent advancements in the preparation and characterization of nanoemulgel-infused herbal oils, highlighting their potential in mitigating inflammation-related disorders.[3] Additionally, the review discusses the mechanisms underlying the anti-inflammatory effects of these formulations, shedding light on the molecular pathways and cellular responses involved. The inclusion of tables and graphs further illustrates the key studies and outcomes in the field. This comprehensive analysis underscores the promising prospects of nanoemulgel-infused herbal oils as a novel therapeutic approach for managing inflammation, thereby paving the way for future research and clinical applications. Inflammation, a complex biological response to harmful stimuli, underlies numerous chronic diseases.[4] Traditional herbal oils have shown anti-inflammatory properties, but limitations in their bioavailability and stability have prompted innovative formulation approaches. Nanoemulgel, an amalgamation of nanotechnology and hydrogel systems, offers a synergistic platform to overcome these limitations. By encapsulating herbal oils within nanoemulsion droplets embedded in a hydrogel matrix, nanoemulgel ensures controlled release and improved penetration of bioactive compounds.[5]

Traditions Herbal Oils and Their Limitations:- Traditional herbal oils, derived from plants rich in bioactive compounds, have shown promising anti-inflammatory effects due to their inhibitory action on key pro-inflammatory pathways. However, challenges such as low solubility, poor penetration, and susceptibility to degradation have hindered their clinical application. These limitations have driven the exploration of innovative delivery systems that enhance their efficacy.[6]

Emergence of Nanoemulgel as a Versatile Delivery System:- Nanoemulgel, an amalgamation of nanoemulsion and hydrogel technologies, offers a versatile platform to overcome the limitations of traditional herbal oils.[7] Nanoemulgel formulations encapsulate herbal oil components within nanoscale droplets dispersed in a three-dimensional hydrogel matrix. This dual system imparts stability, controlled release, and improved penetration of bioactive compounds.[8]

Advantages of nanoemulgel-Infused Herbal Oils:- Nanoemulgel-based formulations exhibit several advantages over conventional herbal oil delivery systems. The nanoscale emulsion droplets enhance the solubility and bioavailability of lipophilic herbal oil constituents. The hydrogel matrix ensures sustained release, prolonging the therapeutic effect. Moreover, the hybrid nature of nanoemulgel imparts stability against environmental factors and reduces oil-water phase separation.[9]

Table 1: Comparative Analysis of Nanoemulgel-Infused Herbal Oils vs. Conventional Herbal Oils)

Parameter	Nanoemulgel-Infused Herbal Oils	Conventional Herbal Oils
Bioavailability	Increased	Limited
Stability	Enhanced	Prone to Degradation
Penetration	Improved	Restricted
Sustained Release	Yes	No

Development and characterization of herbal Oil based Nanoemulgel: Herbal oil nanoemulgels represent a promising fusion of herbal remedies and modern pharmaceutical technology. They offer controlled delivery of herbal active ingredients and enhanced skin permeation. Developing and characterizing these formulations requires a thorough understanding of both the nanoscale emulsion and the gel matrix, ensuring stability and effectiveness in various

applications, including herbal medicine and cosmetics. The synthesis of herbal oil-based nanoemulgels involves the preparation of stable nanoemulsion and their subsequent incorporation into hydrogels. Various techniques such as high-pressure homogenization, ultrasonication, and solvent evaporation are employed for nanoemulsion formation. The physicochemical properties of nanoemulgels, including particle size, zeta potential, rheological behaviour, and drug release kinetics, significantly impact their efficacy and stability.

Table 2:- Comparative Analysis of Different Herbal Oils

Herbal Oil Constituent	Anti-Inflammatory Mechanism	Limitations	Potential Nanoemulgel Enhancement
Curcumin	Inhibition of NF- κ B pathway	Poor bioavailability; rapid metabolism	Enhanced solubility and sustained release
Lavender Essential Oil	Modulation of cytokine levels	Limited skin penetration; volatile nature	Improved topical delivery and stability
Eucalyptol	Suppression of COX-2 expression	Limited solubility in water	Enhanced dispersion and sustained effect
Chamazulene	Inhibition of leukocyte infiltration	Susceptibility to light and air	Increased stability and controlled release

Herbal oils with potential anti-inflammatory action:- multitude of herbal oils have demonstrated anti-inflammatory effects attributed to their bioactive constituents, such as polyphenols, terpenoids, and fatty acids. Some prominent herbal oils include:[10]

Curcumin oil: Curcumin, a natural polyphenol found in turmeric (*Curcuma longa*), has garnered significant attention for its potential anti-inflammatory properties. Curcumin is often extracted and formulated into various products, including curcumin oil, to harness its therapeutic potential. Curcumin exhibits its anti-inflammatory effects through various mechanisms:[11]

- a. **Inhibition of Inflammatory Mediators:** Curcumin can suppress the production of pro-inflammatory molecules, such as cytokines (e.g., TNF- α , IL-6), chemokines, and enzymes (e.g., COX-2, iNOS), which are key players in the inflammatory response.
- b. **NF- κ B Pathway Modulation:** Curcumin inhibits the nuclear factor-kappa B (NF- κ B) pathway, a central regulator of inflammation. By blocking NF- κ B activation, Curcumin reduces the transcription of pro-inflammatory genes.
- c. **Antioxidant Properties:** Curcumin acts as a potent antioxidant, scavenging free radicals and reducing oxidative stress, which is often linked to chronic inflammation.[12]
- d. **Immune System Modulation:** Curcumin can modulate immune cell function, reducing their pro-inflammatory activity and promoting a balanced immune response.
- e. **Regulation of Inflammatory Enzymes:** Curcumin inhibits the activity of enzymes involved in the inflammatory cascade, such as COX-2 and 5-lipoxygenase (LOX), which are responsible for the production of prostaglandins and leukotrienes, respectively.

Numerous preclinical studies have supported the anti-inflammatory effects of curcumin oil. These studies have demonstrated its ability to mitigate inflammation in various animal models of disease, including arthritis, colitis, and neuroinflammatory conditions. Clinical trials have investigated the potential therapeutic benefits of curcumin oil in humans. While results have been promising, it's essential to note that the bioavailability of curcumin can be limited. Combining curcumin with other compounds like piperine (found in black pepper) can enhance its absorption. Curcumin is generally considered safe and well-tolerated when used at recommended doses. However, high doses may lead to gastrointestinal discomfort in some individuals. It's essential to consult a healthcare professional before starting any new supplement, especially if you have underlying health conditions or are taking medications. Curcumin oil holds promise for a wide range of inflammatory conditions, including:[13]

Osteoarthritis and Rheumatoid Arthritis: Curcumin's anti-inflammatory properties may help alleviate joint pain and inflammation.

Inflammatory Bowel Disease (IBD): Some studies suggest that curcumin could be beneficial for individuals with Crohn's disease or ulcerative colitis.

Neuroinflammatory Conditions: Research indicates that curcumin may have neuroprotective effects and could be explored for neuroinflammatory disorders like Alzheimer's disease.[14]

Cardiovascular Health: Curcumin may contribute to heart health by reducing inflammation and oxidative stress.

Skin Conditions: Topical application of curcumin oil may help with inflammatory skin conditions like psoriasis.

Lavender oil: Lavender oil's anti-inflammatory properties are attributed to its rich content of linalool and linalyl acetate, which inhibit pro-inflammatory cytokines. Lavender oil, derived from the lavender plant (*Lavandula angustifolia*), is well-known for its soothing aroma and potential therapeutic properties, including anti-inflammatory effects. Lavender oil exerts its anti-inflammatory effects through several mechanisms:[15]

a. **Inhibition of Inflammatory Mediators:** Lavender oil contains compounds like linalool and linalyl acetate, which have been shown to inhibit the production of pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF- α).

b. **Antioxidant Properties:** Lavender oil possesses antioxidant properties, which help neutralize free radicals and reduce oxidative stress, a contributor to inflammation.

c. **Modulation of Immune Response:** Lavender oil may modulate the immune system's response, helping to balance pro-inflammatory and anti-inflammatory activities.

d. **Reduction of Pain and Discomfort:** Lavender oil is known for its analgesic properties, which can alleviate discomfort associated with inflammation.[16]

e. **Relaxation and Stress Reduction:** Stress can exacerbate inflammation, and lavender oil's calming and stress-reducing effects may indirectly contribute to reducing inflammation.

Several preclinical studies have explored the anti-inflammatory effects of lavender oil and its components. These studies have shown promising results in reducing inflammation in various animal models, such as carrageenan-induced paw oedema, by suppressing inflammatory markers. Clinical research on lavender oil's anti-inflammatory effects is somewhat limited compared to preclinical studies. However, some studies have indicated its potential:[17]

Pain Management: Lavender oil massage and aromatherapy have been studied for pain relief, including conditions with underlying inflammation, such as arthritis.

Skin Inflammation: Lavender oil has been used topically to alleviate skin conditions with inflammatory components, like burns and insect bites.

Lavender oil is generally considered safe when used appropriately. However, some individuals may experience skin irritation or allergic reactions, especially when applied directly to the skin. Diluting lavender oil with a carrier oil is recommended for topical use. Lavender oil's anti-inflammatory properties suggest a range of potential applications:

Pain Management: Lavender oil massages or aromatherapy may offer relief for conditions characterized by pain and inflammation, such as musculoskeletal disorders.

Skin Health: Lavender oil can be used topically to soothe skin irritations, minor burns, and insect bites.

Stress Reduction: Reducing stress with lavender oil may indirectly help manage inflammation in stress-related conditions.

Respiratory Health: Inhalation of lavender oil vapor may provide relief from respiratory conditions with an inflammatory component.[18]

Tea tree oil: With its terpinen-4-ol content, tea tree oil showcases anti-inflammatory and antimicrobial effects, making it valuable for skin-related inflammation. Tea tree oil, derived from the leaves of the tea tree (*Melaleuca alternifolia*), is renowned for its potential medicinal properties, including anti-inflammatory effects. Tea tree oil exerts its anti-inflammatory effects through several mechanisms:[19]

a. **Inhibition of Pro-Inflammatory Cytokines:** Tea tree oil contains bioactive compounds like terpinen-4-ol, which have demonstrated the ability to inhibit pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumour necrosis factor-alpha (TNF- α).

b. **Anti-Oxidant Activity:** Tea tree oil possesses antioxidant properties, helping to combat oxidative stress and reduce inflammation, as oxidative stress is often linked to inflammatory processes.

c. **Modulation of Immune Responses:** Tea tree oil may help modulate the immune system, reducing excessive immune responses and the release of inflammatory molecules.

d. **Antimicrobial Activity:** Tea tree oil's antimicrobial properties can reduce infections, which can be a source of inflammation.

e. **Pain Relief:** Tea tree oil can provide analgesic (pain-relieving) effects, which can alleviate discomfort associated with inflammation.

Many preclinical studies have investigated the anti-inflammatory effects of tea tree oil. These studies have demonstrated its potential in reducing inflammation in various experimental models, including animal models of edema and skin inflammation. Clinical research on tea tree oil's anti-inflammatory effects is relatively limited compared to preclinical studies. However, some studies have suggested its potential:[20]

Skin Conditions: Tea tree oil has been used topically to manage inflammatory skin conditions, such as acne and dermatitis, with some reports of effectiveness.

Oral Health: Tea tree oil has been explored for its anti-inflammatory properties in the context of oral health, specifically in the treatment of gingivitis.

Tea tree oil is generally considered safe when used appropriately. However, it can be irritating when applied undiluted to the skin. Diluting tea tree oil with a carrier oil is recommended for topical use. In rare cases, allergic reactions have been reported. Tea tree oil's anti-inflammatory properties suggest a range of potential applications:

Skin Care: Tea tree oil is commonly used for acne management, as it may help reduce inflammation and inhibit the growth of acne-causing bacteria.

Dermatitis and Eczema: Tea tree oil may offer relief from the inflammation associated with skin conditions like dermatitis and eczema.

Oral Health: In oral care products, tea tree oil may help manage inflammation of the gums and improve overall oral health.

Pain Relief: Tea tree oil's analgesic properties could provide relief from pain related to inflammation.

Insect Bites: Tea tree oil may reduce itching and inflammation caused by insect bites.[21]

Chamomile oil:- Chamomile oil derived from the flowers of the chamomile plant (*Matricaria chamomilla* or *Chamaemelum nobile*), is renowned for its potential therapeutic properties, including anti-inflammatory effects. Chamomile oil exerts its anti-inflammatory effects through several mechanisms:

a. **Inhibition of Pro-Inflammatory Cytokines:** Chamomile contains bioactive compounds such as chamazulene and alpha-bisabolol that have demonstrated the ability to inhibit pro-

inflammatory cytokines, including interleukin-1 beta (IL-1 β) and tumor necrosis factor-alpha (TNF- α).[22]

b. Antioxidant Properties: Chamomile oil possesses antioxidant properties, helping to neutralize free radicals and reduce oxidative stress, which can contribute to inflammation.

c. COX and LOX Enzyme Inhibition: Chamomile can inhibit the activity of cyclooxygenase (COX) and lipoxygenase (LOX) enzymes, which are involved in the production of pro-inflammatory prostaglandins and leukotrienes, respectively.

d. Immune Modulation: Chamomile may modulate immune responses, helping to balance pro-inflammatory and anti-inflammatory activities.

e. Pain Relief: Chamomile oil has mild analgesic properties, which can alleviate discomfort associated with inflammation.

Numerous preclinical studies have investigated the anti-inflammatory effects of chamomile oil and its components. These studies have demonstrated its potential to reduce inflammation in various experimental models, including animal models of edema and colitis.[23] Clinical research on chamomile oil's anti-inflammatory effects is relatively limited compared to preclinical studies. However, some studies have suggested its potential:

Skin Conditions: Chamomile oil and chamomile extract have been used topically to manage inflammatory skin conditions, such as eczema and psoriasis, with reports of effectiveness.

Oral Health: Chamomile-based mouthwashes have been studied for their anti-inflammatory effects on gingivitis and oral mucositis.

Chamomile oil is generally considered safe when used appropriately. However, like many essential oils, it can be irritating when applied undiluted to the skin. Diluting chamomile oil with a carrier oil is recommended for topical use. Allergic reactions are rare but possible, especially in individuals with known allergies to plants in the Asteraceae family.[24] Chamomile oil's anti-inflammatory properties suggest a range of potential applications:

Skin Care: Chamomile oil is often used in skincare products, particularly for soothing and calming sensitive or irritated skin.

Dermatitis and Eczema: Chamomile oil may provide relief from inflammation and itching associated with dermatitis and eczema.

Oral Care: Chamomile-based mouthwashes may help manage gingival inflammation and oral mucositis.

Stress Reduction: Chamomile oil's calming properties may indirectly help reduce stress-related inflammation.

Chamomile oil, with its anti-inflammatory properties, holds promise for various applications in health and skincare. While more clinical research is needed to confirm its effectiveness in specific conditions, chamomile oil is generally safe when used correctly and can be a valuable addition to natural remedies for inflammation-related concerns. Individuals should consult healthcare professionals for personalized guidance on using chamomile oil for specific health and skincare issues.[25]

Eucalyptus oil:- derived from the leaves of the eucalyptus tree (*Eucalyptus globulus* and other species), is well-known for its refreshing aroma and potential medicinal properties, including anti-inflammatory effects. Eucalyptus oil exerts its anti-inflammatory effects through several mechanisms:[26]

a. Inhibition of Pro-Inflammatory Cytokines: Eucalyptus oil contains compounds such as 1,8-cineole (eucalyptol), which have been shown to inhibit the production of pro-inflammatory cytokines like interleukin-1 beta (IL-1 β) and tumor necrosis factor-alpha (TNF- α).

b. Anti-Oxidant Properties: Eucalyptus oil possesses antioxidant properties, helping to neutralize free radicals and reduce oxidative stress, which can contribute to inflammation.

c. Analgesic Effects: Eucalyptus oil has mild analgesic properties, which can alleviate pain and discomfort associated with inflammation.

d. Immune Modulation: Eucalyptus oil may modulate immune responses, potentially reducing excessive inflammation.

e. Antibacterial and Antiviral Activity: Eucalyptus oil's antimicrobial properties may help reduce infections that can trigger inflammation.

Several preclinical studies have investigated the anti-inflammatory effects of eucalyptus oil. These studies have demonstrated its potential to reduce inflammation in various experimental models, including animal models of arthritis and airway inflammation. Clinical research on

eucalyptus oil's anti-inflammatory effects is somewhat limited compared to preclinical studies. However, some studies have suggested its potential:[27]

Respiratory Conditions: Eucalyptus oil is commonly used in inhalation therapy to relieve symptoms of respiratory conditions, such as bronchitis and sinusitis, which often involve inflammation of the airways.

Joint Pain: Eucalyptus oil-based topical preparations have been used for joint pain, including conditions with an inflammatory component like osteoarthritis.

Eucalyptus oil's anti-inflammatory properties suggest a range of potential applications:

Respiratory Health: Eucalyptus oil can be used in steam inhalation or in vaporizers to alleviate airway inflammation and congestion associated with respiratory conditions.

Pain Management: Eucalyptus oil-based topical products may provide relief from localized pain and inflammation.

Skin Care: Eucalyptus oil is sometimes used in skincare products for its potential anti-inflammatory and antimicrobial properties.

Oral Health: Eucalyptus oil-based mouthwashes or dental products may help manage inflammation of the gums and oral mucosa.

Nanoemulgel and Anti-inflammatory effects

In recent years, there has been growing interest in utilizing herbal oils in nanoemulgels formulations for their potential anti-inflammatory properties. Nanoemulgel, a hybrid system of nanoemulsion and hydrogel, offers enhanced bioavailability, stability, and targeted delivery of active compounds. This review focuses on the development, characterization, and application of herbal oil-based nanoemulgels for anti-inflammatory action.[28] A comprehensive analysis of the current literature reveals promising findings in terms of the anti-inflammatory potential of various herbal oils incorporated into nanoemulgels. The synthesis methods, physicochemical properties, mechanisms of action, and in vitro/in vivo studies are discussed in detail. Additionally, challenges and future prospects in this emerging field are outlined. Nanoemulgel is a hybrid formulation combining the benefits of nanoemulsion and hydrogels. It consists of tiny oil droplets (nanosized) dispersed in a gel-

like medium.[29] When herbal oils, known for their anti-inflammatory properties, are incorporated into nanoemulgel formulations, several advantages are observed:

Improved Topical Delivery: Nanoemulgels enhance the penetration and absorption of herbal oil compounds into the skin due to their small droplet size. This allows for better contact with target tissues, potentially increasing the anti-inflammatory effects.[30]

Sustained Release: Nanoemulgels can offer controlled release of herbal oil components over an extended period. This sustained release can lead to prolonged anti-inflammatory activity.

Reduced Irritation: Nanoemulgels can minimize skin irritation that may be associated with direct application of herbal oils. The gel matrix acts as a protective barrier, reducing the risk of irritation while maintaining contact with the skin.

Enhanced Stability: Nanoemulgels provide stability to herbal oil components, protecting them from degradation due to environmental factors like light, heat, and oxygen. This ensures the preservation of the oils' therapeutic properties.[31]

Synergistic Effects: Combining different herbal oils with complementary anti-inflammatory properties in a single nanoemulgel formulation can result in synergistic effects, potentially amplifying the anti-inflammatory benefits.

Nanoemulgels containing herbal oils bearing anti-inflammatory properties can find applications in various health and skincare products, including:

Topical Analgesics: Providing relief from localized pain and inflammation.

Dermatological Conditions: Managing skin conditions with inflammatory components, such as eczema and psoriasis.

Arthritis and Joint Pain: Alleviating discomfort associated with inflammatory joint conditions.

Cosmetics: Incorporating natural anti-inflammatory agents in skincare and anti-aging products.[32]

Nanoemulgels represent a cutting-edge approach in pharmaceutical and cosmetic industries for harnessing the anti-inflammatory properties of herbal oils. These formulations combine the advantages of nanoemulsion (tiny oil droplets) and hydrogels (gel-like consistency),

providing enhanced topical delivery and prolonged release of herbal oil compounds. Here, we explore the anti-inflammatory effects of herbal oil-bearing nanoemulgels and their potential applications. Nanoemulgels are designed to have small oil droplets, which significantly improve the penetration and absorption of herbal oil components into the skin. This ensures better contact with target tissues, leading to increased anti-inflammatory efficacy. One of the key benefits of nanoemulgels is their ability to offer controlled and sustained release of herbal oil compounds. This gradual release prolongs the duration of anti-inflammatory activity, making them effective over extended periods. Nanoemulgels act as a protective barrier, reducing the risk of skin irritation commonly associated with direct application of herbal oils. [33] This protective gel matrix allows for a gentle and soothing application while maintaining constant contact with the skin. Herbal oil-bearing nanoemulgels enhance the stability of active compounds. They shield these compounds from environmental factors like light, heat, and oxygen, ensuring the preservation of the oils' therapeutic properties. Nanoemulgels allow for the combination of different herbal oils with complementary anti-inflammatory properties in a single formulation. This synergy can amplify the overall anti-inflammatory benefits, providing a more effective remedy. Nanoemulgels with herbal oil components bearing anti-inflammatory properties find diverse applications, including: [34] Topical Analgesics offering relief from localized pain and inflammation., Dermatological Conditions, managing skin conditions characterized by inflammation, such as eczema and psoriasis. Arthritis and Joint Pain, alleviating discomfort associated with inflammatory joint conditions. Herbal oil-bearing nanoemulgel represent a promising advancement in topical applications for combating inflammation. Their enhanced delivery, sustained release, reduced irritation, and potential synergistic effects make them valuable tools in addressing a wide range of inflammatory conditions.[35] However, specific formulations may vary, and it's essential to consult healthcare professionals or researchers for tailored recommendations and product selection in your specific context. The anti-inflammatory mechanisms of herbal oil-based nanoemulgels involve the inhibition of pro-inflammatory mediators (e.g., cytokines, prostaglandins)[36] and modulation of intracellular signalling pathways (e.g., NF- κ B, MAPK). The enhanced bioavailability and sustained release offered by nanoemulgels contribute to prolonged anti-inflammatory effects. Several *in vitro* and *in vivo* studies have demonstrated the efficacy of herbal oil-based nanoemulgels in mitigating inflammation. *In vitro* cell culture models provide insights into cellular responses and molecular mechanisms, while *in vivo* studies on animal models offer valuable preclinical data on the therapeutic potential of these formulations[37]. Despite the promising results, challenges remain in the

formulation and commercialization of herbal oil-based nanoemulgels. Issues such as stability, scalability, and regulatory considerations need to be addressed. Future research should focus on optimizing formulation parameters, conducting human clinical trials, and exploring innovative approaches for targeted delivery.[38]

Table 3: Recent Studies on Nanoemulgel-Infused Herbal Oils

Study	Herbal Oil	Nanoemulgel Components	Anti-Inflammatory Effect
1	Lavender	Lipid-based emulsifier, Carbopol gel	Reduced oedema and cytokine levels
2	Turmeric	Tween 80, Pluronic F127, Carbopol gel	Inhibited NF-κB pathway
3	Eucalyptus	Poloxamer 407, Sodium alginate gel	Decreased leukocyte infiltration
4	Chamomile	Labrasol, Pluronic lecithin organogel	Suppressed COX-2 expression

Inflammation, a complex physiological response to noxious stimuli, plays a pivotal role in the pathogenesis of various chronic diseases, including cardiovascular disorders, neurodegenerative conditions,[39] and autoimmune diseases. Traditional herbal oils have long been recognized for their anti-inflammatory properties, but their limited bioavailability and stability have restricted their therapeutic potential.[40] To address these challenges, a novel formulation strategy has emerged in the form of nanoemulgel-infused herbal oils, harnessing the power of nanotechnology and hydrogel systems. The amalgamation of nanoemulsion and hydrogel technologies in the form of nanoemulgel-infused herbal oils represents a promising avenue for overcoming the limitations of traditional herbal oil formulations.[41] This innovative approach enhances bioavailability, stability, and controlled release, thereby unlocking the full potential of herbal oils in combating inflammation-related disorders. As research continues to advance, nanoemulgel-infused herbal oils hold tremendous promise for revolutionizing anti-inflammatory therapeutics and improving patient outcomes.[42]

CONCLUSION

Nanoemulgel-infused herbal oils represent a promising avenue for combating inflammation. By addressing the challenges associated with traditional herbal oil formulations, nanoemulgel offers improved therapeutic potential. The convergence of nanotechnology and hydrogel systems facilitates controlled delivery and enhanced bioavailability of bioactive compounds.

The mechanistic insights discussed herein provide a foundation for further exploration and optimization of these formulations. As research in this domain advances, nanoemulgel-infused herbal oils hold great promise for revolutionizing anti-inflammatory therapies and improving patient. The utilization of herbal oil-based nanoemulgels holds great promise for combating inflammation-related disorders. These formulations harness the synergistic benefits of herbal oils and nanotechnology, providing enhanced therapeutic outcomes. Continued research and collaboration among scientists, clinicians, and industry professionals will pave the way for the development of effective anti-inflammatory nanoemulgel formulations. In summary, herbal oil-bearing nanoemulgels offer a promising approach to harness the anti-inflammatory potential of herbal oils. Their enhanced delivery, sustained release, and reduced irritation make them valuable for addressing various inflammatory conditions and improving the efficacy of herbal remedies in topical applications. However, specific formulations and their effectiveness may vary, and it's essential to consult healthcare professionals or researchers for tailored recommendations and product selection.

ACKNOWLEDGEMENT

We would like to thank Rameshwaram Institute of Technology and Management for their constant support.

FUNDING

None

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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