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Perspective

Formulation and Stability Testing of Herbal-Nano Emulsions for Topical Anti-Inflammatory Use

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DESCRIPTION

The integration of traditional herbal medicine with modern pharmaceutical nanotechnology has opened new avenues for developing safer and more effective topical formulations for inflammatory skin conditions. Herbal-nano emulsions represent a promising approach to enhance the bioavailability, stability, and therapeutic efficacy of phytochemicals when applied topically. Inflammation of the skin, whether due to dermatitis, injury, or autoimmune disorders, often requires long-term treatment. Conventional anti-inflammatory drugs can pose systemic side effects, particularly when used chronically. Therefore, the focus of this study was the formulation and stability testing of herbal-based nano emulsions using selected plant extracts known for their anti-inflammatory properties, aiming to deliver a potent yet biocompatible topical treatment with prolonged shelf life.

The formulation employed an oil-in-water nano emulsion system, using medium-chain triglycerides as the oil phase and a combination of non-ionic surfactants primarily polysorbate 80 and polyethylene glycol to achieve nanoscale droplet sizes for enhanced dermal absorption.

The emulsions were prepared via high-energy ultrasonication, ensuring homogeneity and particle size reduction to the desired range. Particle size analysis conducted through dynamic light scattering revealed an average droplet size of 98-135 nm, with a polydispersity index of less than 0.2, indicating uniform distribution. The zeta potential measurements were around, suggesting good physical stability due to electrostatic repulsion between the droplets. These parameters were deemed ideal for topical applications, as smaller particles are better retained on the skin surface and penetrate through the stratum corneum without systemic absorption.

To evaluate the effectiveness and stability of the formulation, the emulsions underwent a six-month accelerated stability study under different storage conditions: 4°C, 25°C (room temperature), and 40°C with 75% relative humidity. Parameters such as visual appearance, pH, viscosity, droplet size, and phase separation were monitored at monthly intervals. The formulations maintained their physical integrity with no significant changes in color, odor, or texture. Only minimal increases in droplet size were observed at elevated temperatures, which remained within the acceptable range. The pH remained stable between 5.2 and 5.8, ideal for skin compatibility.

Phytochemical stability was assessed using High-Performance Liquid Chromatography (HPLC) to quantify the active components curcumin, boswellic acid and Epigallocatechin Gallate (EGCG) over time. Results indicated a retention of over 85% of the active compounds after six months under all storage conditions, confirming the protective role of the nano emulsion matrix against oxidation and degradation. Furthermore, anti-inflammatory activity was evaluataed using macrophage cell lines by measuring the inhibition of nitric oxide production after lipopolysaccharide stimulation. The nano emulsions demonstrated significant inhibition compared to control, comparable to those of standard diclofenac gels.

The skin permeation ability of the formulation was tested using Franz diffusion cells with excised porcine skin, revealing enhanced permeation of active compounds from the nano emulsion compared to conventional herbal creams. No signs of skin irritation were noted in patch tests conducted on healthy volunteers, supporting the safety profile of the herbal-based nano emulsions.

Despite the successful outcomes, some limitations were acknowledged. While *in vitro* and ex vivo testing provided promising data, full clinical validation in human inflammatory skin disorders remains necessary to determine efficacy and tolerability under real-world conditions. Additionally, the cost of surfactants and equipment required for nano emulsification may be a barrier to widespread application, especially in low-resource settings. However, the scalability of the production process and the use of natural, biocompatible ingredients make it a strong candidate for commercial development.

CONCLUSION

In conclusion, this study demonstrated that herbal-nano emulsions are a viable and stable platform for topical anti-

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inflammatory therapy. The nano-sized droplets significantly enhanced the delivery and retention of phytochemicals in the skin, while maintaining physical and chemical stability over time. The formulation combined the therapeutic richness of herbal extracts with the precision and efficiency of nanotechnology, offering a safe alternative to synthetic anti-inflammatory creams. These results support further clinical development and commercialization of herbal-nano emulsions, especially as consumers increasingly seek natural and sustainable solutions for skin health. With continued research and refinement, such formulations may soon become a staple in both dermatological and cosmetic pharmaceutical care.