REVIEW ARTICLE

Cutting-Edge Developments in Microemulsion Technology: Diverse Applications, Formulation Innovations, and Future Horizons

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ABSTRACT

Microemulsion technology has emerged as a versatile and dynamic solution with widespread applications across various industries. This review delves into the diverse applications, formulation innovations, and anticipated future trends in microemulsion technology. From pharmaceuticals and food to cosmetics and enhanced oil recovery, the unique properties of microemulsions have paved the way for numerous breakthroughs. We explore the formulation strategies that contribute to their stability and efficiency, shedding light on the key factors influencing their success. Additionally, the article highlights the current landscape of microemulsion applications and discusses how ongoing research is shaping the future of this promising technology.

Keywords: Microemulsions, Applications, Innovations, Future trends

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INTRODUCTION

Microemulsions, colloidal systems with droplet sizes ranging from nanometers to micrometers, have garnered significant attention due to their remarkable stability and versatility. This section provides a brief overview of microemulsion technology and its relevance in diverse industrial sectors.[1,2]

Microemulsion technology involves the formation of stable, transparent, and thermodynamically stable colloidal dispersions known as microemulsions. These systems typically consist of water, oil, surfactant, and co-surfactant, forming nanoscale droplets of one immiscible phase dispersed within another. Microemulsions have gained widespread attention due to their unique properties, such as enhanced stability, optical transparency, and ease of formulation. Here's a breakdown of key aspects related to microemulsion technology:

Components

Oil phase

Often a hydrophobic solvent or oil. The oil phase in a microemulsion is a crucial component that influences the stability, properties, and applications of the resulting colloidal system. The selection of the oil phase depends on the specific requirements of the application, and different types of oils can be used. Here are some common types of oil phases used in microemulsions:

Hydrocarbon Oils

Alkanes and isoparaffins

Saturated hydrocarbons like decane, dodecane, or isoparaffinic oils are commonly used due to their low polarity and good solubilizing capacity.

Mineral oils

Refined from petroleum, mineral oils are stable and have low toxicity. They are often used in cosmetic and pharmaceutical formulations.[3,4]

Vegetable oils

- *Sunflower oil, soybean oil, etc*

These oils are biodegradable and can be suitable for applications where biocompatibility is essential. However, their use might be limited in certain formulations due to their higher polarity.[5,6]

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Ester-based oils

- *Isopropyl myristate, ethyl oleate, etc*

Esters are commonly used as oil phases in microemulsions due to their ability to solubilize both hydrophilic and lipophilic compounds. They are often chosen for cosmetic and pharmaceutical applications.[7]

Silicone oils

- *Dimethicone, cyclomethicone, etc*

Silicone oils are known for their non-greasy feel, high stability, and excellent spreading properties. They are often used in cosmetic and personal care formulations.[8,9]

Terpenes

- *Limonene, d-limonene, etc*

Terpenes are natural oils derived from plants. They are often used as eco-friendly alternatives in microemulsion formulations, particularly in pharmaceutical and cosmetic products. [10]

Fluorinated oils

- *Perfluorohydrocarbons*

These oils are chemically stable and can be used in specialized applications such as drug delivery or imaging due to their unique properties. [11]

The choice of the oil phase depends on various factors, including the desired properties of the microemulsion, the intended application, and the compatibility with other components in the formulation. Additionally, considerations such as toxicity, biodegradability, and regulatory approvals play a role, especially in applications like pharmaceuticals and cosmetics. [12,13]

- *Water phase*

The aqueous component.

- *Surfactant*

Surface-active agent that stabilizes the interface between oil and water.

- *Co-surfactant*

Co-stabilizer aiding in the reduction of interfacial tension.

- *Formation*

Surfactants and co-surfactants play a critical role in the formation and stabilization of microemulsions by reducing interfacial tension between immiscible phases. These amphiphilic molecules help in creating a stable colloidal system. Here are common examples of surfactants and co-surfactants used in microemulsions:

Surfactants

Nonionic surfactants

- *Tweens (Polysorbates)*

Examples include Tween 20, Tween 80. These are polyoxyethylene sorbitan esters and are widely used due to their compatibility with a range of oils and aqueous phases. [14,15]

- *Span series*

Span 20, Span 80, etc., are sorbitan fatty acid esters. They are commonly used in combination with Tween surfactants to achieve a stable microemulsion. [16]

- *Brij series*

Brij 30, Brij 58, etc., are polyoxyethylene alkyl ethers. They are effective nonionic surfactants with varying hydrophobic properties.

Ionic surfactants

- *Cationic surfactants*

Examples include cetyltrimethylammonium bromide (CTAB), and benzalkonium chloride. Cationic surfactants are less common in microemulsions due to their potential toxicity but are sometimes used in specific applications.[17]

- *Anionic surfactants*

Sodium dodecyl sulfate (SDS), sodium lauryl ether sulfate (SLES). Anionic surfactants are less commonly used due to their potential to disrupt the stability of microemulsions, but they can be employed in specific formulations. [18]

Co-surfactants

Alcohols

- *Short-chain alcohols*

Ethanol, isopropanol, and n-butanol are commonly used co-surfactants that can enhance the solubilizing capacity and stability of microemulsions.

- *Long-chain alcohols*

Decanol, hexanol, and dodecanol can be used to adjust the hydrophilic-lipophilic balance (HLB) and improve the stability of microemulsions.[19,20]

Polyols

- *Propylene glycol*

Acts as a co-surfactant and also as a humectant. It is commonly used in cosmetic formulations.

- *Glycerol*

Glycerin is another polyol that can be employed as a co-surfactant to improve the stability and viscosity of microemulsions.

Fatty acids and esters

- *Oleic acid*

Oleic acid is often used as a co-surfactant due to its amphiphilic nature, contributing to the stability of microemulsions.[21-23]

- *Isopropyl myristate*

An ester that serves as both an oil phase and a co-surfactant. It is commonly used in cosmetic and pharmaceutical formulations.

Amines

- *Triethanolamine*

Triethanolamine (TEA) can act as a co-surfactant and pH adjuster. It is used in some formulations to improve stability.

Selecting the appropriate combination of surfactants and co-surfactants is crucial for optimizing the microemulsion formulation, ensuring stability, and meeting the specific requirements of the intended application. The choice depends on factors such as the nature of the dispersed phases, desired properties of the microemulsion, and regulatory considerations for the target industry.

Microemulsions are formed spontaneously due to the surfactant and co-surfactant lowering the interfacial tension and promoting the dispersion of the immiscible phases.

They exist in a thermodynamically stable state, resisting coalescence or phase separation over time. [24-26]

- *Stability*

Microemulsions exhibit excellent stability, even in the absence of continuous agitation.

This stability is attributed to the optimal balance between the surfactant and co-surfactant, and the interfacial tension between the phases.[27,28]

Applications

Pharmaceuticals

Microemulsions serve as effective carriers for poorly water-soluble drugs, improving bioavailability.

Food and beverages

Used for encapsulation of flavors, colors, and bioactive compounds.

Cosmetics

Formulation of stable and transparent cosmetic products.

Enhanced oil recovery (EOR)

Microemulsions enhance the recovery of oil from reservoirs.[29-31]

Formulation strategiesand future trends

The formulation of microemulsions involves carefully selecting and combining components to achieve a stable colloidal system with specific properties suitable for various applications. Here are key formulation aspects to consider when developing microemulsions:

Selection of Components

Oil phase

Choose an appropriate oil phase based on the desired characteristics of the microemulsion and the specific application. Consider factors such as solubility, biocompatibility, and stability.

Surfactant

Select surfactants based on their ability to reduce interfacial tension between oil and water phases. Combining hydrophilic and lipophilic surfactants helps in achieving a stable microemulsion.

Co-surfactant

Co-surfactants assist surfactants in stabilizing the microemulsion. Common co-surfactants include alcohols, polyols, and fatty acids.

Water phase

The selection of the aqueous phase depends on the application. It can include pure water or aqueous solutions containing additives, salts, or other ingredients.

Optimizing ratios (Phase Behavior)

Understanding the phase behavior is crucial for achieving a stable microemulsion. Constructing phase diagrams helps identify the optimal ratios of oil, water, surfactant, and co-surfactant to create a thermodynamically stable system.

Surfactant-to-oil ratio (SOR) and water-to-surfactant ratio (W/S)

The SOR and W/S ratios influence the size and stability of microemulsion droplets. Optimizing these ratios is essential for achieving the desired properties and performance.

Temperature and pH considerations

The temperature can affect the phase behavior and stability of microemulsions. Consider the temperature conditions during formulation and potential changes in the application environment.

pH can influence the charge and stability of surfactant molecules. Choose pH conditions that are compatible with the components and application requirements.[32-34]

Recent Developments in Microemulsion Formulations[8,9]

Microemulsion formulations have undergone significant advancements, shaped their efficacy and expanded their applications. The following highlights key developments in microemulsion formulations:

Nanostructured delivery systems

Recent research focuses on incorporating nanotechnology into microemulsion formulations, resulting in nanostructured systems with improved stability, controlled release, and enhanced bioavailability. This approach opens avenues for precise drug delivery in pharmaceutical applications.[34,35]

Environmentally friendly surfactants

Formulators are exploring sustainable options for surfactants, emphasizing eco-friendly alternatives. This shift aligns with the growing demand for environmentally conscious formulations in various industries, from cosmetics to agriculture. [36]

Co-surfactant innovation

The role of co-surfactants is evolving with the introduction of novel compounds. Researchers are experimenting with different alcohols, polyols, and esters to optimize co-surfactant performance, influencing the overall stability and properties of microemulsions. [37]

Responsive and smart microemulsions

Advances in responsive materials have led to the development of smart microemulsions that can adapt to external stimuli such as pH, temperature, or specific triggers. These responsive formulations offer controlled release and targeted delivery in pharmaceutical and cosmetic applications. [38]

Biocompatible oil phases

The quest for safer and biocompatible oil phases has led to the exploration of natural and bio-derived oils. This approach aligns with consumer preferences for clean and sustainable formulations, particularly in the cosmetic and personal care industries.[38,39]

Incorporation of functional additives

Formulators enhance microemulsion functionality by incorporating various additives, such as antioxidants, antimicrobials, and anti-inflammatory agents. This not only improves product stability but also introduces additional therapeutic benefits in pharmaceutical and skincare formulations.[40]

Scale-up strategies

As microemulsion technology gains traction, there is a focus on developing scalable production methods. Innovations in equipment and processes aim to streamline large-scale manufacturing while maintaining the stability and characteristics of microemulsion formulations.[41]

Combination therapies

In pharmaceutical applications, there is a trend toward combining multiple active ingredients within microemulsion formulations. This synergistic approach enhances therapeutic outcomes and addresses complex health challenges.[42,43]

Cross-industry collaborations

Collaborations between industries are fostering interdisciplinary approaches to microemulsion development. Shared expertise from pharmaceuticals, cosmetics, and agrochemicals is accelerating the pace of innovation and broadening the scope of microemulsion applications.[44]

Regulatory compliance and standardization

As microemulsions find their way into diverse industries, efforts are being made to establish regulatory guidelines and industry standards. This ensures consistency in formulations, quality, and safety across different applications. [45]

These developments underscore the dynamic nature of microemulsion formulations, with ongoing research poised to unlock new possibilities and address challenges in diverse sectors. The future holds promise for even more tailored and sustainable microemulsion solutions across various industries.[45,46]

Stability enhancements

Incorporate stability-enhancing additives such as antioxidants or antimicrobial agents to prevent degradation and microbial growth.

Consider the use of co-surfactants or co-solvents to improve the solubility of certain components or enhance the overall stability of the microemulsion.[47]

Characterization techniques

Implement characterization techniques such as dynamic light scattering (DLS), droplet size analysis, and rheological measurements to assess the stability and properties of the microemulsion.

Scale-up considerations

Account for the challenges associated with scaling up microemulsion production. The transition from laboratory-scale to industrial-scale may involve adjustments in equipment and formulation parameters.

Regulatory compliance

Ensure that the selected components comply with regulatory standards for the intended application. This is particularly critical in pharmaceuticals, cosmetics, and food industries.

Incorporation of active ingredients

For applications like pharmaceuticals or cosmetics, consider the incorporation of active ingredients. Determine the compatibility of these ingredients with the microemulsion system.[47,48]

Eco-friendly formulations

Explore the use of eco-friendly surfactants and co-surfactants to align with sustainability goals and reduce environmental impact.

By carefully addressing these formulation aspects, researchers and formulators can create microemulsions with tailored properties, stability, and performance for diverse applications across industries. Regular optimization and adaptation based on specific requirements and technological advancements contribute to the ongoing development of microemulsion technology.

Nanotechnology integration

Exploring the integration of microemulsions into nanotechnology applications.

Smart delivery systems

Development of responsive microemulsions for targeted and controlled drug delivery.

Sustainable formulations

Emphasis on environmentally friendly surfactants and co-surfactants.

In conclusion, microemulsion technology continues to be a dynamic and promising field with diverse applications. Ongoing research and innovations in formulation strategies are expected to expand the reach of microemulsions, offering solutions to various challenges in industries such as pharmaceuticals, food, cosmetics, and energy. [49]

Formulation innovations

Detailed exploration of cutting-edge formulation strategies that contribute to the stability and efficacy of microemulsions. This includes discussions on surfactant and cosurfactant selection, phase behavior, and the influence of additives. Special emphasis is placed on recent advancements that enhance the overall performance of microemulsion formulations. [49,50,51]

Applications across industries

A comprehensive review of the varied applications of microemulsion technology, encompassing pharmaceuticals, food and beverage, cosmetics, and enhanced oil recovery.

Case studies illustrate the successful implementation of microemulsions in different fields, emphasizing their role as effective carriers for active ingredients. [50,51]

Current Trends

Examining the present state of microemulsion technology, this section explores ongoing research and development efforts. Discussions cover emerging applications, market trends, and collaborations driving innovation in the field. Insights into the latest advancements provide a snapshot of the current landscape.[51,52]

Microemulsions find diverse applications across various industries due to their unique properties, stability, and versatility. Here are some notable and diverse applications of microemulsions:

Pharmaceuticals

- *Drug delivery*

Microemulsions enhance the solubility and bioavailability of poorly water-soluble drugs, improving their absorption and therapeutic efficacy.

- *Topical formulations*

Microemulsions are used in creams, gels, and lotions for transdermal drug delivery, offering improved skin penetration and controlled release.[48,49,51]

Cosmetics and personal care

- *Skin care products*

Microemulsions serve as stable bases for creams, lotions, and serums, providing a smooth texture and improved delivery of active ingredients.

- *Hair care products*

Microemulsions are utilized in shampoos and conditioners for enhanced dispersion of oils and vitamins, contributing to improved hair health. [50,51,52]

Food and beverage

- *Flavor and fragrance delivery*

Microemulsions are used to encapsulate and deliver flavors, colors, and fragrances in food products, ensuring better dispersion and controlled release.

- *Nutraceuticals*

Microemulsions aid in the formulation of functional food and beverage products, enhancing the solubility and absorption of bioactive compounds. [48-50]

- *Enhanced oil recovery (EOR)*

Microemulsions are employed in the oil and gas industry to recover residual oil from reservoirs, improving extraction efficiency.

Agriculture

- *Pesticide formulations*

Microemulsions are used as carriers for pesticides, herbicides, and fungicides, improving their dispersion and effectiveness in crop protection.

- *Textile industry*

Microemulsions find application in the textile industry for dyeing and finishing processes, providing stable dispersions and efficient delivery of dyes and chemicals.

- *Cleaning and detergents*

Microemulsions are utilized in cleaning products and detergents for their ability to solubilize and disperse oils and stains effectively.

- *Biotechnology*

In biotechnological applications, microemulsions are explored for enzyme immobilization and bio-catalysis, offering stable environments for enzymatic reactions.

- *Nanostructured materials synthesis*

Microemulsions serve as templates for the synthesis of nanostructured materials, including nanoparticles and nanocapsules, with applications in electronics, catalysis, and materials science.

- *Photovoltaics*

In solar cell technology, microemulsions are investigated for the fabrication of thin films and as templates for the synthesis of nanomaterials, contributing to the development of efficient photovoltaic devices.

These diverse applications showcase the adaptability of microemulsions in addressing challenges and improving processes across different industries. Ongoing research continues to explore new frontiers, expanding the range of applications and unlocking the full potential of microemulsion technology. [51,52]

Future Perspectives

Anticipating the future trends in microemulsion technology, this section discusses potential developments and challenges. Insightful projections shed light on how this technology may evolve, including novel applications, formulation enhancements, and potential breakthroughs that could shape the industry in the coming years.

The future horizons of microemulsions are marked by ongoing research and development efforts aimed at expanding their capabilities, improving formulations, and exploring novel applications.[53] Here are some potential future visions for microemulsions.[53]

Targeted drug delivery in medicine

Developments in nanotechnology and nanomedicine may lead to more sophisticated microemulsion-based drug delivery systems with the ability to target specific cells or tissues. This could enhance the precision of treatments and reduce side effects.

Smart and responsive microemulsions

Integration of stimuli-responsive materials may pave the way for microemulsions that can respond to external factors such as pH, temperature, or specific triggers. This responsiveness could be harnessed for controlled release and targeted delivery in pharmaceutical and cosmetic applications.[54]

- *Biodegradable and sustainable formulations*

The exploration of eco-friendly surfactants, co-surfactants, and oil phases may become more prevalent, aligning with the global trend toward sustainable and biodegradable formulations. This could address environmental concerns and meet consumer preferences for green products.[55]

- *Combination therapies in pharmaceuticals*

The future may see an increased focus on combining multiple therapeutic agents within microemulsions for synergistic effects. This approach could revolutionize the treatment of complex diseases and enhance overall therapeutic outcomes.

- *Advanced functional food and nutraceuticals*

Microemulsions may play a crucial role in the development of functional foods and nutraceuticals, with optimized formulations designed to improve the delivery of bioactive compounds, vitamins, and antioxidants for enhanced health benefits.[56]

- *Innovations in enhanced oil recovery (EOR)*

Ongoing research in the oil and gas industry may lead to advanced microemulsion formulations designed for more efficient enhanced oil recovery processes. This could contribute to increased yields and improved sustainability in the extraction of fossil fuels.[57]

- *Personalized skincare and cosmetics*

Future microemulsion-based cosmetic formulations may be tailored to individual skin types and conditions, providing personalized skincare solutions. This could involve the incorporation of specific active ingredients for targeted benefits.

- *Advanced nanomaterial synthesis*

Continued exploration of microemulsion templates may lead to the synthesis of advanced nanomaterials with unique properties for applications in electronics, catalysis, and materials science. The precision and stability offered by microemulsion templates could contribute to the development of innovative materials.[58]

- *Cross-industry collaborations*

Collaborative efforts between industries, such as pharmaceuticals, cosmetics, and agrochemicals may accelerate the development of versatile microemulsion formulations. Shared knowledge and interdisciplinary approaches could lead to breakthroughs in diverse applications.[59]

- *Standardization and regulatory guidelines*

As microemulsions become more mainstream, there may be an increased focus on standardization and the establishment of regulatory guidelines to ensure consistency, safety, and quality across different industries.[60]

The future of microemulsions holds promise for groundbreaking innovations that will not only expand their applications but also contribute to advancements in various scientific and industrial fields.[61] Continued collaboration, technological breakthroughs, and a focus on sustainability are likely to shape the next generations of microemulsion formulations.[62]

CONCLUSION

Summarizing the key findings, this section underscores the significance of microemulsion technology in diverse applications. The review concludes by emphasizing the potential for continued growth and innovation in this dynamic field. This review article aims to provide a comprehensive overview of microemulsion technology, exploring its current applications, formulation strategies, and future trends, thereby contributing to the understanding and advancement of this promising technology.

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REFERENCES

1. Yadav K, Soni G, Choudhary D, Khanduri A, Bhandari A, Joshi. Microemulsions for enhancing drug delivery of hydrophilic drugs: Exploring various routes of administration. Med. Drug Dis. 2023; 16:100-162. Available from: https://doi.org/10.1016/j.medidd.2023.100162
2. Madhav S and Gupta D. A review on microemulsion based system. International Journal of Pharmaceutical Sciences and Research. 2011; 2(8): 1888-1899. Available from: http://dx.doi.org/10.13040/IJPSR.0975-8232.2(8).1888-99
3. Chhatrani B and Dr. Shah D. A Review on Microemulsion Based Gel: A Novel Approach for Enhancing Topical Delivery of Hydrophobic Drug. International Journal of Pharmacy and Pharmaceutical Research. 2017; 8(4): 19-35.
4. Azad S, Nagul M, Babu C, Kumar R and Naik V. Micro Emulsions: An Overview and Pharmaceutical Applications. World Journal of Current Medical and Pharmaceutical Research. 2018; 2(2): 201-205. Available from: https://doi.org/10.37022/WJCMPR.2020.2222
5. Wagh S, Patil M, Musale A, Mahajan H and Wagh R. A review on microemulsion for drug delivery system. World Journal of Current Medical and Pharmaceutical Research. 2020; 9(7): 20-23.
6. Kumar S, Moorthi D, Saravanan R, Gopal U and Shanmugam V. Microemulsions as carrier for novel drug delivery: a review. International Journal of Pharmaceutical Sciences Review and Research. 2011;10(2): 68-72.
7. Nikhat T, Kasar S, Dr. Gangurde A, Shoaib S, Deore P, Abuzar M, Kolapkar J, Sunil N. A Review On: Microemulgel as a Topical Drug Delivery System. European Chemical Bulletin. 2023;12(12): 733-752.
8. Suhail N, Alzahrani K, Basha J, Kizilbash N, Zaidi A, Ambreen J. and Khachfe H. Microemulsions: Unique Properties, Pharmacological applications and Targeted Drug Delivery. Frontiers in Nanotechnology. World Journal of Current Medical and Pharmaceutical Research. 2021; 3:754889. Available from: https://doi.org/10.3389/fnano.2021.754889
9. Sowmya N, Chandrakala V and Srinivasan S. Review on: effect of oil, surfactant and cosurfactant on microemulsion. International Journal of Current Pharmaceutical Research. 2018; 14(4): 23-27.
10. Mane V, Patil V, Mane M and Patil S. A review on microemulsion

– a recent approach for topical drug delivery system. International Journal of Creative Research Thoughts. 2021;9(7): 18-22.
11. Raut P and Khandre R. A Review on Microemulsion. International Journal of Creative Research Thoughts. 2022; 10(11): 32-38.
12. Pirdhankar S, Pawar S and Dr. Tasgaonkar R. Review on: microemulsion. International Journal of Novel Research and Development. 2023; 8(1): 201-202.
13. Singh V, Bushettii S, Appala R, Ahmad R,Singh M, and Bisht A, et al. Microemulsions as Promising Delivery Systems: A Review. Indian Journal of Pharmaceutical Education and Research. 2011; 2(2):45-46.
14. Sabale V, Vora S. Formulation and evaluation of microemulsion-based hydrogel for topical delivery. International Journal of Pharmaceutical Investigation. 2012; 2: 32-48. Available from: 10.4103/2230-973X.104397
15. Gadhave A and Waghmare J. A short review on microemulsion and its application in extraction of vegetable oil. International Journal of Research in Engineering and Technology. 2014;3(9): 20-39.
16. Shinde S, Panchal K and Dhondwad M. Review article - microemulsion: novel drug delivery system. International Journal for Scientific Research and Development. 2020; 5(2): 32-41.
17. Chauhan N. and Upadhyay P. A Review on Micro Emulsion Drug Delivery System as Bioavailability Enhancement Tool Using Solubilisations Technique. International Journal for Scientific Research and Development. 2021; (4): 21(4): 28-33.
18. Rokad A, Review on microemulsion: theory, methods of preparation. Journal of Emerging Technologies and Innovative Research. 2023; 10(2): 41-48.
19. Sujatha B, Himabindu E, Dr. Bttu S and Dr. Konde A. Microemulsions-A review on microemulsion, International Journal of Pharmaceutical Sciences and Research. 2020; 12(6):750-753. Available from: https://doi.org/10.31531/2231-5896.1000105
20. Muzaffar F,Singh U and Chauhan L. Review on microemulsion as futuristic drug delivery. Indian Journal of Physiology and Pharmacology. 2019; 5(3): 39-53.
21. Saini J, KaurJ, Nautiyal U, Kumar S, Singh D and Anwar F. Microemulsions: A potential novel drug delivery system. International Journal of Pharmaceutical and Medicinal Research. 2014; 2(1):15-20.
22. Singh P, Iqubal M, Kumar V and Shuaib M. Microemulsions: Current Trends in Novel Drug Delivery. International Research Journal of Pharmacy. 2014; 1(1):39-51. 10.1016/j.ijpharm.2007.08.057.
23. Tiwari N and Sivakumar A. Biomedical application of microemulsion delivery systems: A review. Journal of Research in Pharmacy. 2022; 26(5): 1052-1064.
24. Narang A, DeMarre D and Gaoc D. Stable drug encapsulation in micelles and microemulsions: Review. International Journal of Pharmaceutics. 2007; 345: 9–25. Available from: 10.1016/j.ijpharm.2007.08.057.
25. US Patent 6902756: Transparent high oil loaded microemulsions.
26. US Patent 6623765: Microemulsion and micelle systems for solubilizing drugs.
27. Lawrencea J and Gareth R. Microemulsionbased media as novel drug delivery systems. Advanced Drug Delivery Reviews. 2000; 45: 89–121. 10.1016/s0169-409x(00)00103-4.
28. Danielsson I , Lindman B: The definition of microemulsion. Colloids and Surfaces. 1981; 3: 391-392. 10.1016/0166-6622(81)80064-9
29. Yuan Y. Investigation of microemulsion system for transdermal delivery of meloxicam. International Journal of Pharmaceutics. 2006; 321: 117-123. Available from: 10.1016/j.ijpharm.2006.06.021
30. Hoar T, Schulman J. Transparent water-inoil dispersions, the oleopathic hydro micelle. Nature. 1943; 152: 102–103.
31. Danielsson A, Lindman B. The definition of a microemulsion, Colloids and Surfaces. Indian Journal of Pharmaceutical Education and Research. 1981; 3: 391–392. Available from: 10.1038/152102a0
32. Kumar K. Microemulsions as Carrier for Novel Drug Delivery: A Review. International Journal of Pharmaceutical Research. 2011; 10: 37-45.
33. Madhav. S and Gupta. D. A review on microemulsion based system. International Journal of Pharmaceutical Research. 2011; 2(8): 188-197. Available from: http://dx.doi.org/10.13040/IJPSR.0975-8232.2(8).1888-99
34. Ghosh P. and Murthy R. Microemulsions: A Potential Drug Delivery System. Current Drug Delivery. 2006; 3: 167-180. 10.2174/156720106776359168.
35. Chandra A and Sharma PK. Microemulsions: An Overview. Pharmainfonet. 2008; 6(2): 201-218.
36. Kunieda H. Microemulsions. The Journal of Physical Chemistry A. 1988; 92: 185. Available from: 10.1080/01932699708943740
37. Mukherjee K, Microemulsions : Overview. Journal of Colloid and Interface Science. 1997; 187: 327. Available from: 10.37022/WJCMPR.2020.2222.
38. Aboofazeli R and Lawrence M. Investigations into the formation and characterization of phospholipid microemulsions. Pseudo-ternary phase diagrams of systems containing water-lecithin-alcoholisopropyl myristate. International Journal of Pharmaceutics. 1993; 93: 161-175. Available from: https://doi.org/10.1016/0378-5173(95)00125-3
39. Kumar J, Microemulsions- Potential Carrier for Improved Drug Delivery. International Journal of Pharmaceutical Sciences. 2011; 1(2): 25-31.
40. Troy D, Remington J and Beringer P. Remington: The Science and Practice of Pharmacy (21st ed.). Philadelphia: Lippincott Williams & Wilkins, 2006; 336: 886-87.
41. Kumar P and Mittal K. Handbook of Micro emulsion Science and Technology; 1st Edn; CRC Press, New York, 1999. p 25.
42. Lawrence M and Rees G. Micro emulsion-based media as novel drug delivery systems. Advanced Drug Delivery Reviews. 2000; 45(1): 89-121. Available from: 10.1016/s0169-409x(00)00103-4.
43. Vandamme T, Microemulsions as ocular drug delivery systems: recent developments and future challenges. Progress in Retinal and Eye Research. 2002; 21(1): 15. Available from: 10.1016/s1350-9462(01)00017-9.
44. Flanagan J and Singh H. Microemulsions: a potential delivery system forbioactives in food. Critical Reviews in Food Science and Nutrition. 2006; 46(3): 221-37. Available from: 10.1080/10408690590956710.
45. Ghosh P and Murthy R. Micro emulsions: a potential drug delivery system. Current Drug Delivery. 2006; 3(2): 167-80. Available from: 10.2174/156720106776359168.
46. Jadhav K, Shaikh I, Ambade K and Kadam V. Applications of micro emulsion-based drug delivery system. Current Drug Delivery. 2006; 3(3): 267-73. Available from: 10.1002/chin.200637269
47. Spernath A and Aserin A. Microemulsions as carriers for drugs

and nutraceuticals. Advances in Colloid and Interface Science. 2006; 128-130: 47-64. Available from: 10.1016/j.cis.2006.11.016.

48. Vyas S. Theory and practice in novel drug delivery system; CBS Publishers, New Delhi, 2009. p 115-116.
49. Prince L. A theory of aqueous emulsions. Negative interfacial tension at the oil/water interface. Journal of Colloid and Interface Science. 1976; 23: 165- 173.
50. Ramadan R and Devarajan P; Micro emulsion. Indian Drugs, 2003; 139-146.
51. Shaji J and ReddyM. Micro emulsion as drug delivery system, Pharma Times, 2004; 139-146.
52. Leon La and Herbert A. The Theory and practices of Industrial pharmacy; Liberman pospecial Indian edition. 2009, p 507-530.
53. Rasal A, Mahajan HS, Shaikh HT, Surana SJ. Development and characterization of nasal mucoadhesive microemulsion of sumatriptan succinate. Indian Journal of Novel Drug Delivery. 2010;2:103–8
54. Shah P, Swarnkar D. Development and characterization of microemulsion containing antihypertensive agent using factorial design. Journal of Pharmacy and Bioallied Sciences. 2012; 4: 69–70. Available from: 10.4103/0975-7406.94143
55. Gohel MC, Nagori SA. Fabrication and evaluation of hydrogel thickened microemulsion of ibuprofen for topical delivery. Indian Journal of Pharmaceutical Education and Research. 2010; 44:189–96.
56. Patel MR, Patel RB, Parikh JR, Solanki AB, Patel BG. Effect of formulation components on the in vitro permeation of microemulsion drug delivery system of fluconazole. AAPS PharmSciTech. 2009; 10:917–23. Available from: 10.1208/s12249-009-9286-2
57. Dreher F, Walde P, Luisi PL, Elsner P. Human skin irritation studies of a lecithin microemulsion gel and of lecithin liposomes. Skin Pharmacology and Physiology. 1996; 9: 124–9. Available from: 10.1159/000211408.
58. Odds FC, Webster CE, Abbott AB. Antifungal relative inhibition factors: BAY 1-9139, bifonazole, butoconazole, isoconazole, itraconazole (R 51211), oxiconazole, sulconazole, terconazole and vibunazole compared in vitro with nine established antifungal agents. Journal of Antimicrobial Chemotherapy. 1984; 14:105–14. Available from: 10.1093/jac/14.2.105.
59. Suppaibulsuk B, Prasassarakich P, Rempel GL. Factorial design for nanosized polyisoprene synthesis via differential microemulsion polymerization. Polymers for Advanced Technologies. 2018; 21:467–75. Available from: 10.1002/pat.1450
60. Touitou E, Godin B, Karl Y, Bujanover S, Becker Y. Oleic acid, a skin penetration enhancer, affects Langerhans cells and corneocytes. Journal of Controlled Release. 2020; 80:1–7. Available from: 10.1016/s0168-3659(02)00004-4
61. Lawrencea M, Gareth D. Microemulsion-based media as novel drug delivery systems. Advanced Drug Delivery Reviews. 2000; 45: 89–121. Available from: 10.1016/s0169-409x(00)00103-4
62. Gibaud S, Attivi D. Microemulsions for oral administration and their therapeutic applications. Expert Opinion on Drug Delivery. 2012; 9: 937–51. Available from: 10.1517/17425247.2012.694865