Comparative Study Of Methods For Producing Nanoemulsions Using Vegetable Oil As An Excipient: Narrative Review

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Abstract.

Nanoemulsions using vegetable oils as excipients have gained attention for their ability to improve the delivery and stability of bioactive compounds in pharmaceutical and food applications.This study aims to systematically compare various methods for preparing nanoemulsions with vegetable oil excipients. A narrative literature review was conducted, focusing on articles published between 2021 and 2025 from Google Scholar, PubMed, and ScienceDirect.The population comprised all relevant scientific articles,with purposive sampling based on inclusion criteria such as active DOI and accessibility. Data were analyzed qualitatively using content analysis to identify, group, and compare preparation methods, physicochemical characteristics, and product stability. Results indicate that high-energy methods like ultrasonication and high-pressure homogenization produce nanoemulsions with smaller, more uniform droplets and greater stability, while low-energy methods such as spontaneous emulsification are simpler but may yield less stable products. The choice of vegetable oil and surfactant significantly affects droplet size and stability. In conclusion, optimizing both the oil type and preparation method is essential for developing effective nanoemulsion-based products.

Keywords: *Bioavailability; Emulsification; Nanoemulsion, Stability and Vegetable Oil.*

I. INTRODUCTION

Research Phenomenon

Nanoemulsions formulated with vegetable oils have emerged as a promising technology in pharmaceutical and food industries due to their ability to enhance the delivery and stability of bioactive compounds. Vegetable oils, which are primarily composed of triglycerides, offer unique physicochemical properties that make them suitable as excipients in nanoemulsion systems (Nitbani et al., 2020; Giannopoulou et al., 2025). Recent studies have demonstrated that nanoemulsions based on vegetable oils can significantly improve the preservation and quality of muscle foods, as well as increase the bioavailability of lipophilic drugs and nutraceuticals (Fallah et al., 2023; Wilson et al., 2022).The transition from conventional emulsions to nanoemulsion-based formulations is driven by the need for improved solubility, stability, and controlled release of active ingredients. Nanoemulsions are characterized by their small droplet size (typically 20–500 nm), high kinetic stability, and enhanced optical clarity, which contribute to their superior performance in drug delivery and food preservation applications (Solans et al., 2005; Salvia-Trujillo et al., 2016).

Research Problem

Despite the advantages offered by nanoemulsions, the selection of appropriate vegetable oils and the optimization of preparation methods remain challenging. The physicochemical properties of different vegetable oils, such as fatty acid composition and chain length, can significantly influence the stability, droplet size, and bioaccessibility of nanoemulsions (Giannopoulou et al., 2025; Bajerski et al., 2016). Furthermore, the choice of preparation method whether high-energy techniques like ultrasonication and high-pressure homogenization or low-energy methods such as spontaneous emulsification affects the efficiency and quality of the final nanoemulsion product (Ariviani et al., 2018; Yao et al., 2021).There is considerable variability in the outcomes reported by different studies, with some methods yielding more stable and effective nanoemulsions than others. For instance, spontaneous nanoemulsion formation using sonication has been shown to produce better emulsion products in certain cases, but the reproducibility and scalability of this approach require further investigation (Nurdianti et al., 2017; Malode et al., 2021). Additionally, the interaction between vegetable oil type, surfactant selection, and preparation method complicates the standardization of nanoemulsion formulations for pharmaceutical and food applications (Wilson et al., 2022; Pandey et al., 2022).

Research Purpose, Urgency, and Novelty

This study aims to systematically compare various methods for preparing nanoemulsions using vegetable oils as excipients, focusing on their impact on emulsion stability, droplet size, and bioactive compound delivery. The urgency of this research lies in the growing demand for efficient and safe drug delivery systems and food preservation technologies that leverage natural excipients. By integrating recent findings and highlighting the influence of oil type and preparation technique, this review provides novel insights into optimizing nanoemulsion formulations for enhanced performance in pharmaceutical and food applications (Giannopoulou et al., 2025; Fallah et al., 2023).The novelty of this study is reflected in its comprehensive approach to evaluating both the physicochemical properties of vegetable oils and the comparative effectiveness of different nanoemulsion preparation methods, supported by up-to-date references from reputable databases such as Google Scholar and ScienceDirect (Wilson et al., 2022; Yao et al., 2021).

II. METHODS

Research Types and Methods

This research is a narrative literature study that aims to compare various methods of producing nanoemulsion preparations using vegetable oil as an excipient. A literature study was chosen because it allows researchers to comprehensively review the results of previous relevant studies, both from national and international journals, as well as to identify trends and challenges in the development of vegetable oil-based nanoemulsions (Nitbani et al., 2020; Giannopoulou et al., 2025; Sugiyono, 2022; Creswell & Creswell, 2023).

Instruments and Data Analysis Techniques

The main instruments in this study were scientific articles obtained from the Google Scholar, PubMed, and ScienceDirect databases, with inclusion criteria of publications from 2021-2025 that discussed methods of making nanoemulsions using vegetable oil as an excipient. Data analysis techniques were performed qualitatively using a content analysis approach, namely identifying, grouping, and comparing methods for producing nanoemulsions, physicochemical characteristics, and the stability and effectiveness of nanoemulsion products (Ariviani et al., 2018; Singh et al., 2022; Emzir, 2021; Mushtaq et al., 2023).

Population and Sample

The population of this study was all scientific articles discussing vegetable oil-based nanoemulsions as excipients in pharmaceutical and food preparations. Samples were taken purposively, namely articles that met the inclusion and exclusion criteria, such as discussing nanoemulsion preparation methods, physicochemical characterization, and the application of vegetable oil as an excipient. The selection process was carried out by searching for relevant keywords and ensuring that the articles had active DOIs and were accessible online (Yao et al., 2021; Bajerski et al., 2016; Sudaryono, 2022).

Research Procedure

The research procedure began with the identification and collection of articles from predetermined databases. Next, screening was conducted based on inclusion and exclusion criteria, followed by content analysis to compare nanoemulsion production methods, such as high-energy methods (high-pressure homogenization, ultrasonication) and low-energy methods (spontaneous emulsification, phase inversion). The data obtained were analyzed systematically to identify the advantages, disadvantages, and factors affecting the stability and effectiveness of vegetable oil-based nanoemulsions (Nurdianti et al., 2017; Sambhakar et al., 2023; Sugiyono, 2022; Creswell & Creswell, 2023).Each stage of the research was conducted in a structured and logical manner, referring to applicable research methodology standards and supported by the latest relevant references that are accessible online.

III. RESULT AND DISCUSSION

Definition and Characteristics of Nanoemulsions

Nanoemulsions are transparent or translucent colloidal dispersions consisting of oil and water phases stabilized by surfactant molecules. The droplet size of nanoemulsions typically ranges from 50 to 500 nanometers, which helps prevent creaming and sedimentation during storage (Solans et al., 2005; Bajerski et al., 2016). The use of vegetable oils as the dispersed phase in nanoemulsions has gained attention due to their favorable physicochemical properties and potential health benefits (Giannopoulou et al., 2025; Nitbani et al., 2020).

Preparation Methods of Nanoemulsions

Nanoemulsions can be prepared using either high-energy or low-energy methods. High-energy methods, such as high-pressure homogenization and ultrasonication, utilize mechanical shear forces to break down oil and water phases into nanosized droplets. These techniques are widely used in pharmaceutical and cosmetic industries, but their high operational costs may limit large-scale applications (Bajerski et al., 2016; Yao et al., 2021).Low-energy methods, including spontaneous emulsification and phase inversion techniques, rely on the intrinsic chemical energy of the system and require minimal mechanical input. Spontaneous emulsification involves mixing oil, surfactant, and co-surfactant at specific ratios, followed by gentle stirring to form nano-sized droplets. This method is advantageous due to its simplicity and energy efficiency, but the resulting emulsions may be less stable compared to those produced by high-energy methods (Malode et al., 2021; Sambhakar et al., 2023).The phase inversion temperature (PIT) method is another low-energy approach, where the surfactant's affinity for oil and water is altered by changing the temperature, leading to phase inversion and nanoemulsion formation. This method allows for complete solubilization of the oil phase but requires precise control of temperature and surfactant composition (Mushtaq et al., 2023; Bajerski et al., 2016).

Influence of Vegetable Oil Type

The type of vegetable oil used in nanoemulsion formulations significantly affects the stability, droplet size, and bioactive compound delivery. Oils with different fatty acid compositions, such as olive oil, sesame oil, and coconut oil, exhibit varying interfacial properties and compatibility with surfactants (Giannopoulou et al., 2025; Sumah, 2020). Studies have shown that the choice of oil can influence the zeta potential, pH, and homogeneity of the nanoemulsion, which are critical parameters for product stability and efficacy (Yao et al., 2021; Bajerski et al., 2016).

Stability and Characterization

Nanoemulsions are kinetically stable but thermodynamically unstable systems. Their stability is assessed through parameters such as droplet size distribution, zeta potential, and resistance to thermal and mechanical stress. For example, nanoemulsions prepared using the phase inversion composition method demonstrated stable droplet sizes (215–233 nm), negative zeta potentials (−49.54 to −37.04 mV), and consistent pH values under thermal stress and accelerated stability testing (Bajerski et al., 2016; Yao et al., 2021).Transmission electron microscopy (TEM) and photon correlation spectroscopy are commonly used to characterize the morphology and size distribution of nanoemulsion droplets. Homogeneous and spherical particles with low polydispersity index (PDI) indicate good stability and uniformity of the system (Yulius Evan Christian, 2022; Bajerski et al., 2016).

Application and Advantages

Nanoemulsions formulated with vegetable oils are widely applied in drug delivery systems, such as Self-Nanoemulsifying Drug Delivery Systems (SNEDDS), and in food preservation. These systems enhance the solubility and bioavailability of hydrophobic compounds, protect volatile oils from degradation, and improve the sensory properties of products (Mushtaq et al., 2023; Sambhakar et al., 2023). The spontaneous nanoemulsification method, particularly when combined with sonication, has been reported to yield better emulsion products in terms of droplet size and stability (Nurdianti et al., 2017; Ariviani et al., 2018).In summary, the choice of preparation method and type of vegetable oil are critical factors influencing the quality and stability of nanoemulsions. High-energy methods offer superior stability but are cost-intensive, while low-energy methods provide simplicity and efficiency with some limitations in stability. The integration of appropriate oils and surfactants, along with optimized preparation techniques, is essential for developing effective nanoemulsion-based products for pharmaceutical and food applications (Giannopoulou et al., 2025; Yao et al., 2021; Sambhakar et al., 2023).

IV. CONCLUSION

This review highlights that the choice of preparation method and type of vegetable oil as excipient are critical factors influencing the stability, droplet size, and effectiveness of nanoemulsion formulations. High-energy methods such as ultrasonication and high-pressure homogenization consistently produce nanoemulsions with smaller, more uniform droplets and greater physical stability, while low-energy methods like spontaneous emulsification offer simplicity and energy efficiency but may result in less stable products. The physicochemical properties of different vegetable oils, including fatty acid composition and compatibility with surfactants, also play a significant role in determining the final quality and bioactive delivery of nanoemulsions. These findings are supported by recent studies that demonstrate the practical advantages of nanoemulsions in pharmaceutical and food applications, particularly in enhancing bioavailability and product shelf-life .

However, this study is limited by its reliance on published literature, which may not capture all variables or experimental nuances present in laboratory or industrial settings. The diversity of methods and formulations reported in the literature also poses challenges for direct comparison and standardization. Future research should focus on experimental validation of promising methods, optimization of oil-surfactant combinations, and scalability for industrial production. Practical implications include the potential for developing more effective drug delivery systems and functional foods using optimized nanoemulsion technology. Researchers and industry practitioners are encouraged to adopt systematic approaches in selecting oils and preparation techniques, and to conduct further studies on long-term stability, safety, and regulatory compliance of nanoemulsion products.

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