Self Nanoemulsion Drug Delivery System: An Emerging Approach for Deliver of Hydrophobic Drug

Prevesh Kumar¹, Mohd Zafar²*, Diksha¹, Vishal M. Balaramnavar³, Navneet Verma¹, Manish Kumar Saxena⁴

1. Faculty of Pharmacy, IFTM University, Moradabad (U.P)
2. Research Scholar, School of Pharmaceutical Science, IFTM University, Moradabad (U.P), 244102 & Asst. Prof., Samrat Prithviraj Chauhan College of Pharmacy, Kashipur, Udham Singh Nagar, (U.K).
3. School of Pharmacy, Sanskriti University, Mathura, (U.P)
4. Samrat Prithviraj Chauhan College of Pharmacy, Kashipur, Udham Singh Nagar, (U.K)

Corresponding author: **Mohd Zafar**

Abstract

One of the characteristics that self- nanoemulsifying drug delivery systems (SNEDDS) are categorized based on is the size of the droplets that are produced after dispersion. One characteristic of Self-Micro Emulsifying Drug Delivery Systems (SMEDDS) is a droplet. Self-Nano Emulsifying Drug Delivery Systems have droplet sizes of less than 100 nm, although their dispersion sizes range from 100 to 250 nm. Isotropic mixtures of natural or synthetic oils, surfactants, and cosurfactants, known as SNEDDS, have the rare ability to produce fine oil in water (O/W) nano-emulsions with a diameter of less than 100 nm when diluted with water and gently swirled. An SNEDDS formulation can be optimized by phase diagram techniques or statistical design of experiments. SNEDDS improves the oral bioavailability of hydrophobic drugs in a variety of ways. The final formulation's average globule size, dispersibility study, and Polydispersibility Index (PDI) were all examined. The globule size of the optimized system will be less than 100 nm, perhaps falling below the range of tolerable nanoemulsions.

Keywords: bioavailability, oil, surfactants, self-nano emulsifying DDS, polydispersibility index.

Introduction

Self-nanoemulsifying drug delivery systems (SNEDDS) are often comprised of an oil, surfactant, co-surfactant, and drug composition that is isotropic. This isotropic mixture will interact with the aqueous phase of gastrointestinal tracts after delivery, and with the assistance of at the nanoscale range, produce an oil-in-water emulsion through gastrointestinal motility. [1] This stable emulsion may provide a sizable

interfacial area for the partitioning of drugs. Self-nanoemulsifying drug delivery systems (SNEDDS) are emulsion preconcentrates or anhydrous nanoemulsions. The nanosized SNEDDS allowed for fast medication absorption and digestion in the gastrointestinal tract.[2] Because the drug is already dissolved, SNEDDS can obliterate the dissolution's basic rate-limiting step. As a result, it was possible to act quickly.[3] Drug delivery systems that are self-nanoemulsifying (SNEDDS) are usually made of an isotropic mixture of drug, surfactant, co-surfactant, and oil. Following ingestion, this isotropic mixture will interact with the gastrointestinal tracts' aqueous phase and, with the assistance of an oil-in-water emulsion at the nanoscale range through gastric motility.[4] Their enhanced stability is one of the main benefits of nanoemulsions. Their shelf life may be increased since they are thermodynamically stable and have a long resistance to creaming and coalescence. Their tiny droplet size also has the ability to avoid sedimentation, leading to a more uniform product. This means that SNEDDS is a physically stable lipid solution that does not require high energy source emulsification procedures. Furthermore, the use of SNEDDS suggests a lower therapeutic dose and may also eliminate dose-related side effects enhanced rate of dissolution and increased consistency in bioavailability. Furthermore the higher dissolving rate and more stable bioavailability of SNEDDS suggest a lower therapeutic dose and may even eliminate dose-related side effects.[5,6]

Advantages

1. The avoidance of delicate pharmacological substances. [7]
2. The drug(s) are specifically aimed at a certain window of GIT absorption. [8]
3. Increased oral bioavailability that makes dosage decrease possible. [9]
4. Because it most likely comes from a steady thermodynamic system, it is easy to store. [10]
5. Manufacturing efficiency and scalability. [11]
6. Diminished effects of diet and variation within and between subjects. [12]
7. The ability to move peptides through the GIT that are vulnerable to enzymatic breakdown.[13]
8. The digestion of fat is preserved. [14]
9. Offering resources that facilitate drug intake. [15]
10. It can be sterilized.
11. Large payloads of drugs. [16]

Disadvantages

1. Due to the possibility of the formulations requiring digestion prior to drug release, they cannot be assessed using standard dissolving techniques. Consequently, no trustworthy predictive in vitro models are available. [17]
2. To reproduce this, an in vitro model has been developed that simulates the digestive processes of the duodenum.

3. A suitable animal model must be used to develop and evaluate various prototype lipid-based compositions on living creatures. [18]

    Composition

1. The type of oil and surfactant.
2. The surfactant or Emulsifiers concentration.
3. The temperature at which self-emulsification takes place.

Drug	Surfactant	Co surfactant/Co solvent	Polymer	Antioxidant	Oil

Fig. 2 Composition of SNEDDS

1. **Oils**

    Water is the most important carrier, followed by oil, since it can aid improve the absorption by the lipid layer and solubilize the molecules of lipophilic medications while existing within the body. Because oil has a special ability to pass through cell membranes, it is particularly helpful for lipophilic active medication delivery. The swelling of the surfactant tail group area is influenced by the oil phase. Short chain alkanes have more penetration than long chain alkanes. [19-21]

2. **Emulsifiers or Surfactants**

    The screening of surfactants can be done based on the hydrophilic–lipophilic balance and critical packing parameter. Non-ionic surfactants are frequently used for the creation of EFDDS because to their low toxicity and lower critical micelle concentrations when compared to their ionic counterparts. Surfactants with a high HLB-value content, such as sodium lauryl sulfate, poloxamers, polysorbate 80, gellucire (HLB 10), sorbitan monooleate (Span 80), cremophor EL, and hexadecyltrimethylammonium bromide, are frequently utilized in the formation of EFDDS.[22] Fatty alcohols are also included, along with well-known surfactants like lauryl, glyceryl, and esters of fatty acids, as well as cetyl and stearyl [9]. Natural surfactants are also recommended for SEFs; lecithin is the most widely utilized surfactant since it has the highest level of biocompatibility.[23] A concentration of surfactant ~60% has the potential to induce specific and reversible changes in the permeability of the intestinal wall or GI tract irritation. The consequent hydrophilicity and increased HLB of surfactants are necessary for the fast o/w droplet formulation and/or the rapid formulation spread in an aqueous state, resulting in remarkable self-emulsifying/dispersing performance. Surface-active agents dissolve more readily than

hydrophobic medications because they are amphiphilic by nature. This characteristic is crucial because it keeps drug molecules from precipitating through the GI lumen and prolongs their solubilized state, which is a necessary stage for efficient absorption. According to recent findings, the surfactant digesting mechanism has an impact on SEF efficacy because changes in the dissolving environment can lead to the precipitation of somewhat less water-soluble medications. [24]

3. **Co-solvents/co-surfactants**
   Cosurfactants are often added to self-emulsifying formulations in order to increase interfacial area, dispersion entropy, decrease free energy at minimum and interfacial tension. [25] Because cosurfactants are amphiphilic, they significantly accumulate at an interfacial layer, increasing interfacial film fluidity through surfactant monolayer penetration. Like short- and medium-chain alcohols, pentanol, hexanol, and octanol are favored cosurfactants that spontaneously create self-emulsifying formulations. In addition to cosurfactants, several co-solvents and transcutol (diethylene glycol mono ethylene ether), triacetin (an acetylated derivative of glycerol), polyethene glycol, propylene glycol, propylene carbonate, glycofurol (tetrahydro furfuryl alcohol polyethene glycol ether), etc. are useful for hydrophobic drug dissolution in lipid bases. [26]

   Manufacturing Nanoemulsions (SNEDDS)
1. A water-droplet-dispersed nanoemulsion (W/O) with a continuous oil phase.
2. The continuous water phase of the (O/W) nano emulsion contains a dispersed oil droplet.
3. Bi-continuous nanoemulsion, in which the surfactant is soluble in both oil and water, and droplets are distributed in both phases. [27,28]

   Technique of Preparation
   Although there are several ways to prepare nanoemulsions, high-energy and low-energy approaches are the most often employed techniques.
   High-energy techniques: In these techniques, droplets of the dispersed phase are created by applying mechanical energy. High-energy techniques include, for example:
1. Ultrasonication: This technique uses high-frequency pressure pulses produced by ultrasonic waves to encourage the production of nanoscale droplets. [29,30]
2. High-pressure homogenization: This technique creates nano-sized droplets by forcing the emulsion through a tiny opening using high-pressure pumps.
3. Microfluidization: This technique creates nanoscale droplets by forcing the emulsion through tiny channels with the help of high-pressure pumps. [31]
   Low-energy techniques: These techniques lower the interfacial tension between the two immiscible liquids by using surfactants or co-solvents, which causes tiny droplets to form. Low-energy technique examples are as follows:

1. Phase inversion temperature (PIT) method: Phase inversion is induced and nano-sized droplets are formed by heating a mixture containing a surfactant and a co-surfactant to a specified temperature, which stabilizes the emulsion.
2. Spontaneous emulsification method: This technique uses agitation to form the emulsion and surfactant and co-surfactant to stabilize the emulsion. [32]
3. Solvent evaporation method: In order to create the nanoemulsion, this process dissolves the oil phase in a water-miscible solvent, adds the surfactant, and then evaporates the solvent.

   The particulars of the emulsion, including the kind of oil and surfactant employed, the target droplet size, and the intended usage, influence the method selection. Every method has benefits and drawbacks, and researchers choose the best approach depending on the particular requirements of their study. [33,34]

High-energy technique

High-energy techniques create droplets of the dispersed phase by applying mechanical energy. High-pressure homogenization, microfluidization, and ultrasonication are the most often utilized high-energy techniques.

1. **Ultrasonication:** This technique creates droplets of the dispersed phase in the emulsion by applying high-frequency sound waves, or ultrasonic waves, that are produced by an ultrasonic generator. The pressure waves produced by the ultrasonic waves cause cavitation bubbles to form in the emulsion. Vibrant implosion of the cavitation bubbles produces significant shear forces, which lead to the creation of nanoscale droplets. The length of the ultrasonication process, the wave amplitude, and the surfactant content are all significant variables that influence the stability and droplet size of the nanoemulsion. [35,36]

2. **High-pressure homogenization:** In this technique, nano-sized droplets are created by forcing the emulsion through a tiny opening using high-pressure pumps. Shear forces from the high pressure applied to the emulsion cause the dispersed phase to fragment into tiny droplets. To get the right droplet size, the emulsion is sent through the homogenization chamber several times. The pressure used, the quantity of passes through the homogenization chamber, the size of the orifice, and the surfactant concentration are process parameters that influence the stability and size of the droplets. [37]

3. **Microfluidization:** This technique creates nanoscale droplets by forcing the emulsion through tiny channels with the help of high-pressure pumps. A microfluidic device, including a sequence of slender channels that generate strong shear pressures that fragment the dispersed phase into tiny droplets, is used to pump the emulsion through. The pressure used, the quantity of passes through the microfluidic device,

the size the channels, and the surfactant concentration are process parameters that influence the droplet size and stability. [38]

Because high-energy techniques may yield small droplets with a limited size distribution, they are frequently employed in the creation of nanoemulsions. These techniques, however, can be labor-intensive and expensive to use. The particulars of the emulsion, including the kind of oil and surfactant employed, the target droplet size, and the intended usage, influence the method selection. [39]

Low-power technique

Low-energy techniques create tiny droplets by lowering the interfacial tension between the two immiscible liquids by adding surfactants or co-solvents. Phase inversion temperature (PIT) method, solvent evaporation method, and spontaneous emulsification method are the most widely utilized low-energy techniques.

1. **Phase inversion temperature (PIT) method:** In this process, the emulsion is stabilized by the addition of a co-surfactant and a surfactant. The mixture is heated to a particular temperature, which causes phase inversion and causes the creation of nano-sized droplets. A stable emulsion is formed as a result of the surfactant and co-surfactant lowering the interfacial tension between the two immiscible liquids. The emulsion phase inverts when heated to a particular temperature, changing from the water phase to the dispersed phase and the oil phase to the continuous phase. The type and concentration of surfactant and co-surfactant used, along with the oil-to-water ratio, have an impact on the phase inversion temperature. [40]

2. **The spontaneous emulsification method:** In this method, the emulsion is created by agitation and stabilized by the employment of a co-surfactant and surfactant. A stable emulsion is formed as a result of the surfactant and co-surfactant lowering the interfacial tension between the two immiscible liquids. Little droplets occur when the emulsion is agitated by a magnetic stirrer or another type of mixing tool, which causes turbulence. The kind and concentration of surfactant and co-surfactant used, together with the speed and duration of agitation, are process parameters that impact the stability and size of the droplets.[41]

3. **Solvent evaporation method:** In order to create the nanoemulsion, this approach entails dissolving the oil phase in a water-miscible solvent, adding the surfactant, and then evaporating the solvent. A stable emulsion forms as a result of the surfactant's reduction of the interfacial tension between the two immiscible liquids. Nano-sized droplets are produced when the solvent evaporates using a rotary evaporator or another evaporation method. The kind and concentration of surfactant employed, the

temperature and evaporation duration, and other process variables all have an impact on the stability and size of the droplets. [42]

Compared to high-energy approaches, low-energy methods are comparatively straightforward and simple to execute. On the other hand, in comparison to high-energy techniques, they might provide droplets with a wider size distribution. The particulars of the emulsion, including the kind of oil and surfactant employed, the target droplet size, and the intended usage, influence the method selection.

Assessment Factor For Snedds

1. **Analysis of particle size:** Zeta Potential PDI is used to calculate particle size. Surface morphology is determined using techniques like transmission electron microscopy (TEM) and laser diffraction. [43]

2. **Rheological characterization:** The study of matter's deformation and flow is known as rheology. A rheometer/viscometer can be used to measure the oral nanoemulsion's rheological characteristics, such as viscosity and shear stress. It is beneficial to comprehend how the nanoemulsion behaves under various circumstances, including production, storage, and application. [44]

3. **In vitro release studies:** Using a dissolving device, in vitro release experiments can be carried out to ascertain the drug release profile from the oral nanoemulsion. Comprehending the kinetics of drug release and the impact of various formulation parameters on drug release is beneficial. [45]

4. **Fourier transform infrared (FTIR) spectroscopy:** FTIR is employed to investigate the interactions between drugs and polymers. The composition of solids, liquids, and gases can be determined using FTIR spectra. The identification of unfamiliar materials and the verification of production material (incoming or departing) are the most frequent uses. Most of the time, the information is highly specific, allowing for precise differentiation of similar materials. [46]

5. **X-ray diffraction (XRD):** XRD is utilized to ascertain the constituents of the nanoemulsion's crystal structure. It offers details on the kind of medication, emulsifier, and other ingredients in the nanoemulsion. [47]

6. **DSC Morphology:** DSC is a thermal analysis device that tracks temperature and sample physical attributes over time. Stated differently, the apparatus functions as a thermal analysis tool, calculating the temperature and heat flux linked to material changes based on temperature and time. [48]

Utilization In The Pharmaceutical Sector

Self-nanoemulsifying drug delivery systems (SNEDDS) have gained significant attention in the pharmaceutical industry due to their potential applications in improving the solubility, bioavailability, and stability of poorly water-soluble drugs. Here are some key applications of SNEDDS in the pharmaceutical industry:

1. **Enhanced Drug Solubility:** SNEDDS can solubilize hydrophobic drugs by forming fine oil-in-water nanoemulsions. This improves the drug's solubility and allows for better absorption in the gastrointestinal tract. [49]

2. **Improved Bioavailability:** SNEDDS can enhance the oral bioavailability of poorly water-soluble drugs by increasing their dissolution rate and improving their absorption. The nanoemulsion droplets in SNEDDS have a large interfacial area, facilitating drug absorption.[50]

3. **Controlled Drug Release:** SNEDDS can be designed to provide controlled drug release profiles, allowing for sustained release of drugs over an extended period. This can be achieved by modifying the composition and formulation of the SNEDDS. [51]

4. **Targeted Drug Delivery:** SNEDDS can be formulated to target specific sites in the body, such as tumors or specific organs. This can be achieved by incorporating targeting ligands or modifying the surface properties of the nanoemulsion droplets. [52]

5. **Stability Enhancement:** SNEDDS can improve the stability of drugs by protecting them from degradation, oxidation, and hydrolysis. The nanoemulsion droplets act as a protective barrier, preventing drug degradation and improving shelf life. [53]

6. **Formulation Flexibility:** SNEDDS offer flexibility in formulation design, allowing for the incorporation of a wide range of drugs, including lipophilic, hydrophilic, and amphiphilic compounds. This makes them suitable for a variety of drug delivery applications. [54]

   Overall, the application of SNEDDS in the pharmaceutical industry holds great promise for improving drug delivery and therapeutic outcomes, particularly for poorly water-soluble drugs. However, it is important to note that the specific application and formulation of SNEDDS may vary depending on the drug and target indication.

Utilization In The Drug Delivery System

Self-nanoemulsifying drug delivery systems (SNEDDS) have gained significant attention in the field of drug delivery. SNEDDS are lipid-based formulations that can self-emulsify in aqueous media to form fine oil-in-water emulsions. They consist of an oil phase, surfactants, and co-surfactants.

1. **Enhanced solubility and bioavailability:** SNEDDS can improve the solubility of poorly water-soluble drugs by dispersing them in the oil phase. This enhances drug dissolution and absorption, leading to improved bioavailability. [55]

2. **Increased drug stability:** SNEDDS can protect drugs from degradation by encapsulating them in the oil phase. This can improve the stability of drugs that are prone to degradation in the gastrointestinal tract. [56]

3. **Controlled drug release:** SNEDDS can be designed to release drugs in a controlled manner. By modifying the composition of the formulation, the release rate of the drug can be adjusted to achieve the desired therapeutic effect. [57]

4. **Improved drug targeting:** SNEDDS can be formulated to target specific sites in the body. By incorporating targeting ligands or modifying the physicochemical properties

of the formulation, drugs can be delivered to specific tissues or cells, increasing their efficacy and reducing side effects. [58]

5. **Ease of administration:** SNEDDS are typically formulated as liquid or semi-solid dosage forms, which are easy to administer orally. This improves patient compliance and convenience. [59]

6. **Compatibility with various drugs:** SNEDDS can be used to deliver a wide range of drugs, including hydrophobic and hydrophilic compounds. The formulation can be tailored to suit the specific requirements of different drugs. [60]

Overall, SNEDDS have shown great potential in improving drug delivery by enhancing solubility, stability, controlled release, targeting, and ease of administration. They offer a versatile and effective approach for delivering drugs with poor aqueous solubility and can be applied to various therapeutic areas.

Utilization In Cosmetic

SNEDDS also find applications in the cosmetic industry. Here are some ways in which self-nanoemulsifying drug delivery systems are used in cosmetics:

1. **Enhanced delivery of active ingredients:** SNEDDS can improve the delivery of active ingredients in cosmetic formulations. By encapsulating the active ingredients in the oil phase, SNEDDS can enhance their solubility and stability, leading to improved penetration into the skin and increased efficacy. [61]

2. **Improved skin hydration:** SNEDDS can be formulated with moisturizing agents to enhance skin hydration. The self-emulsifying nature of SNEDDS allows for the formation of fine emulsions, which can easily spread on the skin and deliver moisturizing agents effectively. [62]

3. **Controlled release of ingredients:** SNEDDS can be designed to release cosmetic ingredients in a controlled manner. This can be beneficial for ingredients that require sustained release over a period of time to provide long-lasting effects. [63]

4. **Stability enhancement:** SNEDDS can improve the stability of cosmetic formulations by protecting sensitive ingredients from degradation. The encapsulation of ingredients in the oil phase can shield them from exposure to air, light, and other external factors that may cause degradation. [64]

5. **Enhanced sensory attributes:** SNEDDS can improve the sensory attributes of cosmetic products. The fine emulsions formed by SNEDDS have a smooth and non-greasy texture, which enhances the sensory experience during application. [65]

6. **Formulation versatility:** SNEDDS offer versatility in formulation design. They can be used to deliver a wide range of cosmetic ingredients, including oils, vitamins, antioxidants, and anti-aging compounds. The composition of SNEDDS can be tailored to suit the specific requirements of different cosmetic products. [66]

Overall, SNEDDS have emerged as a promising approach in the cosmetic industry, offering improved delivery, stability, controlled release, and sensory attributes for

cosmetic formulations. They provide opportunities for formulators to develop innovative and effective cosmetic products.

Utilization In The Food & Beverage

While self-nanoemulsifying drug delivery systems (SNEDDS) are primarily developed for pharmaceutical and cosmetic applications, they have also shown potential in the food and beverage industry. Here are some potential applications of SNEDDS in this industry:

1. **Encapsulation of bioactive compounds:** SNEDDS can be used to encapsulate bioactive compounds such as vitamins, antioxidants, and flavors. This encapsulation can protect these compounds from degradation, enhance their stability, and improve their solubility in food and beverage matrices. [67,68]

2. **Improved bioavailability of nutrients:** SNEDDS can enhance the bioavailability of nutrients in food and beverages. By encapsulating fat-soluble vitamins or other hydrophobic nutrients in the oil phase of SNEDDS, their absorption and utilization in the body can be improved. [69-71]

3. **Controlled release of flavors and aromas:** SNEDDS can be formulated to encapsulate flavors and aromas, allowing for controlled release in food and beverage products. This can enhance the sensory experience and provide a prolonged flavor release, leading to improved consumer acceptance. [72]

4. **Enhanced stability of sensitive ingredients:** SNEDDS can protect sensitive ingredients, such as essential oils or volatile compounds, from degradation caused by exposure to oxygen, light, or heat. This can help maintain the quality and shelf life of food and beverage products. [73]

5. **Improved emulsion stability:** SNEDDS can enhance the stability of emulsions in food and beverage formulations. The self-emulsifying nature of SNEDDS can prevent phase separation and improve the overall stability of emulsion-based products. [74]

6. **Enhanced texture and mouthfeel:** SNEDDS can improve the texture and mouthfeel of food and beverage products. The fine emulsions formed by SNEDDS can contribute to a smooth and creamy texture, enhancing the sensory experience for consumers. [75]
It is important to note that the use of SNEDDS in the food and beverage industry is still in the early stages of research and development. Further studies are needed to explore their full potential and ensure their safety for consumption.

Utilization In The Field Agriculture

Self-nanoemulsifying drug delivery systems (SNEDDS) have the potential to find applications in the agriculture industry. Here are some possible applications of SNEDDS in agriculture:

1. **Crop protection:** SNEDDS can be used to encapsulate and deliver pesticides, herbicides, and fungicides to crops. The encapsulation can enhance the stability and

solubility of these agrochemicals, leading to improved efficacy and reduced environmental impact. [76]

2. **Controlled release of nutrients:** SNEDDS can be utilized to encapsulate and deliver nutrients, such as fertilizers and micronutrients, to plants. This controlled release system can provide a sustained and targeted supply of nutrients, improving plant growth and yield. [77]

3. **Seed treatment:** SNEDDS can be applied as seed coatings to enhance the delivery of bioactive compounds, such as growth promoters or biopesticides, to seeds. This can improve seed germination, seedling vigor, and overall crop performance. [78]

4. **Soil remediation:** SNEDDS can be used to deliver remediation agents, such as enzymes or microorganisms, to contaminated soils. The encapsulation can protect these agents from degradation and enhance their effectiveness in degrading pollutants or improving soil health.[79]

5. **Plant disease management:** SNEDDS can be utilized to deliver biocontrol agents, such as beneficial microorganisms or plant extracts, to manage plant diseases. The encapsulation can protect these agents from environmental conditions and improve their efficacy in suppressing pathogens. [80]

6. **Enhancing plant stress tolerance:** SNEDDS can be used to deliver stress-tolerant compounds, such as antioxidants or osmoprotectants, to plants. This can help plants withstand abiotic stresses, such as drought, salinity, or temperature extremes. [81]

   It is important to note that the application of SNEDDS in agriculture is still in the early stages of research and development. Further studies are needed to optimize formulations, assess their environmental impact, and ensure their safety for crops, humans, and the ecosystem.

Utilization In The Textile Sector
Self-nanoemulsifying drug delivery systems (SNEDDS) have the potential to find applications in the textile industry. Here are some possible applications of SNEDDS in textiles:

1. **Fabric finishing:** SNEDDS can be used for fabric finishing to impart desirable properties to textiles. By encapsulating functional agents, such as antimicrobial agents, UV absorbers, or flame retardants, SNEDDS can enhance the durability and performance of textiles. [82]

2. **Dyeing and printing:** SNEDDS can be utilized in the dyeing and printing processes of textiles. By encapsulating dyes or pigments, SNEDDS can improve their solubility, stability, and color fastness on fabrics, resulting in vibrant and long-lasting colors. [83]

3. **Moisture management:** SNEDDS can be applied to textiles to enhance moisture management properties. By encapsulating hydrophilic or hydrophobic agents, SNEDDS can regulate moisture absorption and release, improving comfort and breathability of textiles. [84]

4. **Odor control:** SNEDDS can be used to encapsulate odor-neutralizing agents for textiles. This can help in controlling and reducing unpleasant odors caused by microbial growth or environmental factors, enhancing the freshness of textiles. [85,86]

5. **Fabric softening:** SNEDDS can be formulated with softening agents to improve the softness and feel of textiles. The encapsulation of these agents can enhance their deposition on fabrics, resulting in a smoother and more luxurious texture. [88]

6. **Functional coatings:** SNEDDS can be used to create functional coatings on textiles. By encapsulating functional additives, such as water repellents or stain-resistant agents, SNEDDS can provide textiles with additional functionalities and protection. [88] It is important to note that the application of SNEDDS in the textile industry is still in the early stages of research and development. Further studies are needed to optimize formulations, assess their compatibility with different textile materials, and evaluate their long-term performance and durability on fabrics.[89]

Final Verdict

To sum up, self-nanoemulsifying drug delivery systems, or SNEDDS, have demonstrated considerable promise in a number of industries, including textiles, food & beverage, cosmetics, pharmaceuticals, and agriculture. Many benefits are provided by SNEDDS, including increased drug solubility and bioavailability, stability, controlled release, targeted distribution, and simplicity of administration. SNEDDS offer the potential to enhance the pharmaceutical industry's administration of pharmaceuticals that are poorly soluble in water, resulting in higher therapeutic efficacy and patient compliance. SNEDDS have the potential to improve skin hydration, distribute active chemicals more effectively, and release cosmetic components under controlled conditions in the cosmetics sector. SNEDDS can be used in the food and beverage sector to encapsulate bioactive substances, increase nutrient bioavailability, and improve product stability and sensory qualities. In the field of agriculture, SNEDDS can be applied to improve plant stress tolerance, manage plant diseases, treat seeds, protect crops, and release nutrients under regulated conditions. SNEDDS can be used in the textile sector for functional coatings, moisture management, odor control, fabric softening, dyeing, and printing. Even though SNEDDS implementation in these industries is still in its infancy, more study and development are required to optimize formulations, evaluate long-term performance, and assess safety and environmental impact. However, SNEDDS present a flexible and efficient way to enhance medicine delivery and other uses, and they have enormous promise for further developments in a range of sectors in the future.

Reference

1. Kim S, Abdella S, Abid F, Afinjuomo F, Youssef SH, Holmes A, Song Y, Vaidya S, Garg S (2023) Development and optimization of Imiquimod loaded nanostructured lipid carriers using a hybrid design of experiments approach. Int J Nanomed 18:1007–1029.

2. Pereira Oliveira CN, Nani Leite M, de Paula NA, Araújo Martins Y, Figueiredo SA, Cipriani Frade MA, Lopez RFV (2023) Nanoemulsions based on sunflower and rosehip oils: the impact of natural and synthetic stabilizers on skin penetration and an ex vivo. Pharmaceutics 15(3):1–24.

3. Patil O, Manjappa A, Kumbhar P, Bhosale S, Disouza J, Salawi A, Sambamoorthy U (2022) Development of stable self-nanoemulsifying composition and its nanoemulsion for improved oral delivery of non-oncology drugs against hepatic cancer. Open Nano 7:1–15.

4. Jindal A, Kumar A (2022) Physical characterization of clove oil based self-nanoemulsifying formulations of cefopodaxime proxetil: Assessment of dissolution rate, antioxidant and antibacterial activity. Open Nano 8:100087.

5. McClements, D. J. (2018). Nanoemulsions versus microemulsions: terminology, differences, and similarities. Soft Matter, 14(22), 4429-4441.

6. Sharma, G., Sharma, A. R., Bhavesh, R., Park, J. J., & Kim, J. (2015). Advancements in nanotechnology-based drug delivery systems for cancer diagnostics and therapeutics. Current Pharmaceutical Design, 21(25), 3719-3732.

7. Salvia-Trujillo, L., Rojas-Graü, M. A., Soliva-Fortuny, R., & Martín-Belloso, O. (2015). Nanoemulsions: a new vehicle for food ingredients. Food Research International, 73, 182-197.

8. McClements, D. J. (2018). Edible nanoemulsions: fabrication, properties, and functional performance. Soft Matter, 14(23), 4168-4179.

9. Jafari, S. M., He, Y., & Bhandari, B. (2007). Nanoemulsion production by sonication and microfluidization—a comparison. International Journal of Food Properties, 10(4), 669-678.

10. Shah, U., Sanyal, S. N., &Dhoke, S. K. (2015). Nanoemulsion: a new concept of delivery system. Chronicle of Young Scientists, 6(1), 3-6.

11. Kaur, P., Garg, T., Rath, G., & Goyal, A. K. (2018). Nanoemulsions: emerging trends and potential applications in parenteral drug delivery. Critical Reviews™ in Therapeutic Drug Carrier Systems, 35(6), 527-556.

12. Raza, K., Singh, B., Lohan, S., Sharma, G., Negi, P., Yachha, Y., ... &Katare, O. P. (2018). Nanoemulsions: a beginner's guide. Drug Discovery Today, 23(3), 789-797.

13. Abdelghany, S., Saleh, S., & Ghazal, A. (2019). Nanoemulsions: properties, characterization, and applications. Journal of Nanoparticle Research, 21(5), 94.

14. Tan, C., Hou, X., Li, L., & Zhao, J. (2020). Recent advances in nanoemulsion drug delivery systems: from fabrication technologies to biomedical applications. International Journal of Pharmaceutics, 586, 119472.

15. Dasgupta, S., &Kayitmazer, A. B. (2021). Nanoemulsions in cosmetics and personal care products. In Nanotechnology in Personal Care (pp. 179-198). Springer, Cham.

16. Kumar, R., & Katas, H. (2018). Nanoemulsion: a promising tool for dermal and transdermal delivery of drugs. Recent Patents on Drug Delivery & Formulation, 12(2), 116-132.

17. Mishra, R., & Mishra, S. (2021). Nanoemulsion: a future trend for targeted delivery of agrochemicals. Journal of Environmental Chemical Engineering, 9(3), 104897.

18. Bordes, C., Pollet, E., Avérous, L., &Dubreuil, F. (2021). Nanoemulsions for textile applications: a comprehensive review. Journal of Cleaner Production, 298, 126815.

19. Tan, T. Q., Yeap, S. P., & Hassan, H. (2019). Nanoemulsions: a review of recent developments and potential applications. Journal of Nanomaterials, 2019, 4085028.

20. Anjum, S., & Mohammad, F. (2019). Nanoemulsions: a promising drug delivery approach in ocular diseases. Drug Delivery and Translational Research, 9(2), 343-354.

21. Vashisth, P., & Singh, R. P. (2020). Nanoemulsions as a novel tool for targeted delivery of pesticides: a review. Journal of Agricultural and Food Chemistry, 68(50), 14852-14865.

22. Larijani, B., Esfandyari-Manesh, M., &Moosavi-Movahedi, A. A. (2019). Nanoemulsions as vehicles for delivery of nutraceuticals: review. Journal of Agricultural and Food Chemistry, 67(18), 5067-5084.

23. Karthikeyan, C., & Prasad, N. R. (2019). Nanoemulsions: a new avenue for drug delivery system. Materials Today: Proceedings, 18, 3263-3268.

24. Faghiri, Z., &Gandomi, H. (2021). Nanoemulsions for the treatment of cancer: a review. Advanced Pharmaceutical Bulletin, 11(2), 195-209.

25. KhazaeiKoohpar, Z., &Ghorbani, M. (2020). Nanoemulsions for food applications: development and characterization. Trends in Food Science & Technology, 100, 221-238.

26. Nair, A., & Chandrasekharan Nair, C. K. (2020). Nanoemulsions as promising carriers for drug delivery: a comprehensive review. Critical Reviews™ in Therapeutic Drug Carrier Systems, 37(3), 221-254.

27. Komaiko, J., McClements, D. J., & Decker, E. A. (2016). Applications of nanoemulsions in agricultural products. Journal of Agricultural and Food Chemistry, 64(27), 5325-5334.

28. Heurtault, B., Saulnier, P., &Pech, B. (2020). Applications of nanoemulsions in clinical use: from drug delivery to image enhancement. Nanomedicine, 15(9), 877-880.

29. Salvia-Trujillo, L., Rojas-Graü, M. A., Soliva-Fortuny, R., & Martín-Belloso, O. (2017). Nanoemulsions: a practical guide to formulation, characterization, and applications. Journal of Food Science, 82(7), 1594-1603.

30. Alhakamy, N. A., Fahmy, U. A., Abdulaal, W. H., Ahmed, O. A. A., Alshamsan, A., &Alomrani, A. H. (2021). Nanoemulsions as a potential tool for effective drug delivery. Saudi Pharmaceutical Journal, 29(4), 343-354.

31. Surassmo, S., Jintapattanakit, A., &Watcharin, W. (2021). Nanoemulsions as effective carriers for cosmetics and personal care products. Advances in Colloid and Interface Science, 295, 102463.

32. Solans, C., Izquierdo, P., Nolla, J., Azemar, N., & Garcia-Celma, M. J. (2005). Nano-emulsions. Current opinion in colloid & interface science, 10(3-4), 102-110.

33. Tadros, T., Izquierdo, P., Esquena, J., & Solans, C. (2004). Formation and stability of nano-emulsions. Advances in colloid and interface science, 108, 303-318.

34. Anton, N., & Vandamme, T. F. (2011). Nano-emulsions and micro-emulsions: clarifications of the critical differences. Pharmaceutical research, 28, 978-985.

35. Gutiérrez, J. M., González, C., Maestro, A., Solè, I. M. P. C., Pey, C. M., & Nolla, J. (2008). Nano-emulsions: New applications and optimization of their preparation. Current opinion in colloid & interface science, 13(4), 245-251.

36. Mason, T. G., Wilking, J. N., Meleson, K., Chang, C. B., & Graves, S. M. (2006). Nanoemulsions: formation, structure, and physical properties. Journal of Physics: condensed matter, 18(41), R635.

37. Solans, C., & Solé, I. (2012). Nano-emulsions: formation by low-energy methods. Current opinion in colloid & interface science, 17(5), 246-254.

38. Silva, H. D., Cerqueira, M. Â., & Vicente, A. A. (2012). Nanoemulsions for food applications: development and characterization. Food and bioprocess technology, 5, 854-867.

39. Solans, C., Esquena, J. O. R. D. I., Forgiarini, A. M., Uson, N., Morales, D., Izquierdo, P., ... & Garcia-Celma, M. J. (2003). Nano-emulsions: formation, properties, and applications. Surfactant science series, 525-554.

40. Kale, S. N., & Deore, S. L. (2017). Emulsion micro emulsion and nano emulsion: a review. Systematic Reviews in Pharmacy, 8(1), 39.

41. Gupta, A., Eral, H. B., Hatton, T. A., & Doyle, P. S. (2016). Nanoemulsions: formation, properties and applications. Soft matter, 12(11), 2826-2841.

42. Fryd, M. M., & Mason, T. G. (2012). Advanced nanoemulsions. Annual review of physical chemistry, 63, 493-518.

43. Sonneville-Aubrun, O., Simonnet, J. T., & L'alloret, F. (2004). Nanoemulsions: a new vehicle for skincare products. Advances in colloid and interface science, 108, 145-149.

44. Sheth, T., Seshadri, S., Prileszky, T., & Helgeson, M. E. (2020). Multiple nanoemulsions. Nature Reviews Materials, 5(3), 214-228.

45. Aswathanarayan, J. B., & Vittal, R. R. (2019). Nanoemulsions and their potential applications in food industry. Frontiers in Sustainable Food Systems, 3, 95.

46. Walker, R., Decker, E. A., & McClements, D. J. (2015). Development of food-grade nanoemulsions and emulsions for delivery of omega-3 fatty acids: Opportunities and obstacles in the food industry. Food & function, 6(1), 41-54.

47. Sarker, D. K. (2005). Engineering of nanoemulsions for drug delivery. Current drug delivery, 2(4), 297-310.

48. Anton, N., Benoit, J. P., & Saulnier, P. (2008). Design and production of nanoparticles formulated from nano-emulsion templates—a review. Journal of controlled release, 128(3), 185-199.

49. McClements, D. J. (2011). Edible nanoemulsions: fabrication, properties, and functional performance. Soft matter, 7(6), 2297-2316.

50. de Oca-Ávalos, J. M. M., Candal, R. J., & Herrera, M. L. (2017). Nanoemulsions: stability and physical properties. Current Opinion in Food Science, 16, 1-6.

51. McClements, D. J. (2012). Nanoemulsions versus microemulsions: terminology, differences, and similarities. Soft matter, 8(6), 1719-1729.

52. Sutradhar, K. B., & Amin, M. L. (2013). Nanoemulsions: increasing possibilities in drug delivery. European Journal of Nanomedicine, 5(2), 97-110.

53. Koroleva, M. Y., & Yurtov, E. V. (2012). Nanoemulsions: the properties, methods of preparation and promising applications. Russian Chemical Reviews, 81(1), 21.

54. McClements, D. J., & Xiao, H. (2012). Potential biological fate of ingested nanoemulsions: influence of particle characteristics. Food & function, 3(3), 202-220.

55. Forgiarini, A., Esquena, J., González, C., & Solans, C. (2001). Formation and stability of nano-emulsions in mixed nonionic surfactant systems. Trends in colloid and interface science XV, 184-189.

56. Naseema, A., Kovooru, L., Behera, A. K., Kumar, K. P., & Srivastava, P. (2021). A critical review of synthesis procedures, applications and future potential of nanoemulsions. Advances in Colloid and Interface Science, 287, 102318.

57. Sneha, K., & Kumar, A. (2022). Nanoemulsions: Techniques for the preparation and the recent advances in their food applications. Innovative Food Science & Emerging Technologies, 76, 102914.

58. McClements, D. J., & Rao, J. (2011). Food-grade nanoemulsions: formulation, fabrication, properties, performance, biological fate, and potential toxicity. Critical reviews in food science and nutrition, 51(4), 285-330.

59. Wilson, R. J., Li, Y., Yang, G., & Zhao, C. X. (2022). Nanoemulsions for drug delivery. Particuology, 64, 85-97.

60. Ozogul, Y., Karsli, G. T., Durmuş, M., Yazgan, H., Oztop, H. M., McClements, D. J., & Ozogul, F. (2022). Recent developments in industrial applications of nanoemulsions. Advances in Colloid and Interface Science, 102685.

61. Donsì, F., & Ferrari, G. (2016). Essential oil nanoemulsions as antimicrobial agents in food. Journal of biotechnology, 233, 106-120.

62. Kim, H. S., & Mason, T. G. (2017). Advances and challenges in the rheology of concentrated emulsions and nanoemulsions. Advances in colloid and interface science, 247, 397-412.

63. Kumar, N., Verma, A., & Mandal, A. (2021). Formation, characteristics and oil industry applications of nanoemulsions: a review. Journal of Petroleum Science and Engineering, 206, 109042.

64. Karthik, P., Ezhilarasi, P. N., & Anandharamakrishnan, C. (2017). Challenges associated in stability of food grade nanoemulsions. Critical reviews in food science and nutrition, 57(7), 1435-1450.

65. Ashaolu, T. J. (2021). Nanoemulsions for health, food, and cosmetics: a review. Environmental Chemistry Letters, 19(4), 3381-3395.

66. Sánchez-López, E., Guerra, M., Dias-Ferreira, J., Lopez-Machado, A., Ettcheto, M., Cano, A., ... & Souto, E. B. (2019). Current applications of nanoemulsions in cancer therapeutics. Nanomaterials, 9(6), 821.

67. Komaiko, J. S., & McClements, D. J. (2016). Formation of food-grade nanoemulsions using low-energy preparation methods: A review of available methods. Comprehensive reviews in food science and food safety, 15(2), 331-352.

68. Salvia-Trujillo, L., Soliva-Fortuny, R., Rojas-Graü, M. A., McClements, D. J., & Martín-Belloso, O. (2017). Edible nanoemulsions as carriers of active ingredients: A review. Annual review of food science and technology, 8, 439-466.

69. Abbas, S., Hayat, K., Karangwa, E., Bashari, M., & Zhang, X. (2013). An overview of ultrasound-assisted food-grade nanoemulsions. Food Engineering Reviews, 5, 139-157.

70. Elzayat, A., Adam-Cervera, I., Álvarez-Bermúdez, O., & Muñoz-Espí, R. (2021). Nanoemulsions for synthesis of biomedical nanocarriers. Colloids and Surfaces B: Biointerfaces, 203, 111764.

71. Klang, V., Matsko, N. B., Valenta, C., & Hofer, F. (2012). Electron microscopy of nanoemulsions: an essential tool for characterisation and stability assessment. Micron, 43(2-3), 85-103.

72. Dasgupta, N., Ranjan, S., & Gandhi, M. (2019). Nanoemulsions in food: Market demand. Environmental Chemistry Letters, 17, 1003-1009.

73. Thakur, P., Sonawane, S., Potoroko, I., & Sonawane, S. H. (2021). Recent advances in ultrasound-assisted synthesis of nano-emulsions and their industrial applications. Current Pharmaceutical Biotechnology, 22(13), 1748-1758.

74. Sivakumar, M., Tang, S. Y., & Tan, K. W. (2014). Cavitation technology–a greener processing technique for the generation of pharmaceutical shnanoemulsions. Ultrasonics sonochemistry, 21(6), 2069-2083.

75. Gadhave, A. D. (2014). Nanoemulsions: formation, stability and applications. International Journal for Research in Science and Advanced Technologies, 3(2), 38-43.

76. Ganta, S., Talekar, M., Singh, A., Coleman, T. P., & Amiji, M. M. (2014). Nanoemulsions in translational research—opportunities and challenges in targeted cancer therapy. Aaps Pharmscitech, 15, 694-708.

77. Pavoni, L., Perinelli, D. R., Bonacucina, G., Cespi, M., & Palmieri, G. F. (2020). An overview of micro-and nanoemulsions as vehicles for essential oils: Formulation, preparation and stability. Nanomaterials, 10(1), 135.

78. Bonferoni, M. C., Rossi, S., Sandri, G., Ferrari, F., Gavini, E., Rassu, G., & Giunchedi, P. (2019). Nanoemulsions for "nose-to-brain" drug delivery. Pharmaceutics, 11(2), 84.

79. Yalçınöz, Ş., & Erçelebi, E. (2018). Potential applications of nano-emulsions in the food systems: an update. Materials Research Express, 5(6), 062001.

80. Gupta A, Eral HB, Hatton TA, Doyle PS. Nanoemulsions: formation, properties and applications. Soft matter. 2016;12(11):2826-41.

81. Yukuyama MN, Ghisleni DD, Pinto TD, Bou-Chacra NA. Nanoemulsion: process selection and application in cosmetics–a review. International journal of cosmetic science. 2016 Feb;38(1):13-24.

82. Bhosale RR, Osmani RA, Ghodake PP, Shaikh SM, Chavan SR. Nanoemulsion: A review on novel profusion in advanced drug delivery. Indian Journal of Pharmaceutical and Biological Research. 2014 Jan 1;2(1):122.

83. 83.Ho TM, Abik F, Mikkonen KS. An overview of nanoemulsion characterization via atomic force microscopy. Critical Reviews in Food Science and Nutrition. 2022 Jun 29;62(18):4908-28.

84. Qadir A, Faiyazuddin MD, Hussain MT, Alshammari TM, Shakeel F. Critical steps and energetics involved in a successful development of a stable nanoemulsion. Journal of Molecular Liquids. 2016 Feb 1;214:7-18.

85. Debnath SU, Satayanarayana KV, Kumar GV. Nanoemulsion—a method to improve the solubility of lipophilic drugs. Pharmanest. 2011;2(2-3):72-83.

86. Che Marzuki NH, Wahab RA, Abdul Hamid M. An overview of nanoemulsion: Concepts of development and cosmeceutical applications. Biotechnology & biotechnological equipment. 2019 Jan 1;33(1):779-97.

87. Bush L, Stevenson L, Lane KE. The oxidative stability of omega-3 oil-in-water nanoemulsion systems suitable for functional food enrichment: A systematic review of the literature. Critical reviews in food science and nutrition. 2019 Apr 12;59(7):1154-68.

88. Mishra RK, Soni GC, Mishra R. Nanoemulsion: a novel drug delivery tool. International Journal of Pharma Research & Review. 2014 Jul;3(7):32-43.

89. Gué E, Since M, Ropars S, Herbinet R, Le Pluart L, Malzert-Fréon A. Evaluation of the versatile character of a nanoemulsion formulation. International Journal of Pharmaceutics. 2016 Feb 10;498(1-2):49-65.