

Nano-emulsion formulations: Recent advancements and Applications

Abhinav Saini*, Rohit Chandel, Anju Bala

Institute of Pharmaceutical Sciences, IET Bhaddal Technical Campus Ropar, Punjab, INDIA.

ABSTRACT

The innovative Novel Drug Delivery System (NDDS) known as nanoemulsions provide the ability of controlled or regulated drug release, biologically active ingredients, and genetical material. A nanoemulsion is an oily, a surfactant, and a hydrophilic phase, which is a thermodynamically or kinetically stable liquid solution that is optically clear and typically has droplet diameters between 10 and 500 nm. The goal of this study is to create and characterise the best suitable nano-emulsion drug possible in order to maximise the drug's bioavailability. One of the best and most useful dosage forms created using nanotechnology in pharmaceutical formulations is the nanoemulsion. The nano emulsion's extremely small droplets promote better medication absorption and targeting. This review dwells into recent insights of nano-emulsion formulations being explored for their enhanced efficacy in biological systems. Further this review dwells into the various applications of the Nanoemulsions.

Keywords: Applications, Bioavailability, Drug delivery system, Formulation, Nanoemulsion.

Correspondence:

Mr. Abhinav Saini

Assistant Professor, Institute of
Pharmaceutical Sciences, IET Bhaddal
Technical Campus Ropar, Punjab, INDIA.
Email: sainiabhi294@gmail.com

Received: 14-07-2026;

Revised: 27-08-2026;

Accepted: 07-10-2026.

INTRODUCTION

Nanoemulsions are Oil-in-Water (O/W) and Water-in-Oil (W/O) dispersions of two immiscible liquids stabilized with suitable surfactants. The average droplet diameter achieved is typically around 500 nm (Aboofazeli, 2010). The tiny droplet size provides them a clear or cloudy look, unlike the opalescent colour related with coarse emulsion (Aulton and Taylor, 2013). The term nanoemulsion is now and then utilized traded with submicron emulsion or miniemulsion, but ought to not be befuddled with microemulsion. Nanoemulsions have the same bead estimate extend as microemulsions, but vary essentially in auxiliary angles and long-term thermodynamic solidness (McClements, 2012). Nanoemulsions are possible to be made in several forms such as liquids (Tan *et al.*, 2015), creams (Sharma *et al.*, 2013; Al-Edresi and Baie, 2009), sprays (Makidon *et al.*, 2010), gels (Lala and Awari, 2014; Hussain *et al.*, 2016), aerosols (Nasr *et al.*, 2012; Amani *et al.*, 2010) and foams (Tamarkin *et al.*, 2007) increase. It can also be administered by various routes including topical (Mou *et al.*, 2008), oral (Khani *et al.*, 2016), intravenous (Pawar *et al.*, 2014), intranasal, pulmonary (Bhanushali *et al.*, 2009), and ocular (Ammar *et al.*, 2009). They have higher solubilizing ability than simpler micellar dispersions, higher dynamic stability than dense emulsions, and are used in the cosmetic

products and agrochemical (Yukuyama *et al.*, 2016; Wang *et al.*, 2007) industries as hydrophilic bases for natural products. The physical stability of nano-emulsion is directly proportional to the small size of droplets, which can result in classical instability phenomena such as coalescence, creaming and sedimentation. In many cases, Brownian motion is capable enough to cancel dynamic instabilities induced by gravity or viscosity. For parenteral, nanoemulsions have been utilized to solubilize and secure drugs from forceful natural variables (oxidation, pH, hydrolysis) (Zhang *et al.*, 2012), taking advantage of improved permeability and retention effects. To target specific organs and avoid the reticuloendothelial system. Nanoemulsions are classified as multiphase colloidal scatterings and are characterized by their soundness and straightforwardness. The scattered stage is as a rule composed of little particles or beads and encompasses a exceptionally moo oil/water interfacial pressure. Nanoemulsions frame suddenly and effectively, now and then for the most part without tall vitality input. In addition to surfactants, oil phases and water phases, co-surfactants or co-solvents are often used (Jiang *et al.*, 2013).

Depending on composition, three types of nanoemulsions are formed

- **Oil in Water (o/w):** A nanoemulsion in which oil beads are scattered in a persistent hydrophilic stage.
- **Water in Oil:** A nanoemulsion in which water beads are scattered in an oil ceaseless stage.



DOI: 10.5530/lsrc.2.3.23

Copyright Information :

Copyright Author (s) 2026 Distributed under
Creative Commons CC-BY 4.0

Publishing Partner : Manuscript Technomedia, [www.mstechnomedia.com]

Bi-directional continuous

Nanoemulsions in which oil and water microdomains are scattered within the framework. In all sorts of nanoemulsions, the interface is stabilized by fitting combinations of surfactants and/or cosurfactants. The most contrast between emulsions and nanoemulsions is that the previous has great motor soundness but are thermodynamically unsteady and in the long run experience stage partition.

Advantages of nanoemulsions over other dosage forms

- Eliminate irregular absorption.
- Increase absorption capacity.
- Helps solubilize lipophilic drugs.
- Provide hydrophilic dosage forms of water-insoluble drugs.
- Increase bioavailability.
- Products can be provided to patient by multiple routes which includes topical, oral and intravenous.
- Quick and capable penetration of drug molecules.
- Helps in masking of taste.
- Provides the ability to defend against oxidation and hydrolysis as an oil phase agent in O/W emulsions.
- Energy required is very low.
- Liquid form for dosing is seemed to improve patient compliance.
- Thermodynamically Nanoemulsions are stable systems whose stability allows the system to self-emulsify and whose properties are independent of subsequent processes.
- Nanoemulsions can have both lipophilic and hydrophilic compounds.
- Using nanoemulsions as a delivery system might improve efficacy, reduce total dosage and minimize side effects (Trotta, 1999; "Organogel-based nanoemulsions," 2012).

Drawbacks of nanoemulsion system

Use of more concentrations of surfactants and co-surfactants required for nanodroplet stabilization.

Dissolution is limited for high melting point substances.

Surfactants should not be toxic for pharmaceutical applications.

Nanoemulsions soundness is influenced by natural parameters such as temperature and pH. These parameters alter when the

nanoemulsion is managed to the quiet (Sun *et al.*, 2014; Lu *et al.*, 2015).

Components for nanoemulsion formulation

Oil and lipids

Nanoemulsions typically contain 5-20% oil/lipid droplets of O/W emulsions, but can be much larger (up to 70%) (Muheem *et al.*, 2016). Lipids/oils used in nanoemulsions are generally suggested according to drug solubility (Ensign *et al.*, 2012). Soybean oil (Khan *et al.*, 2013; Garti *et al.*, 1983; Sinko *et al.*, 2006) sesame oil (Anuchapreeda *et al.*, 2012; Hwang *et al.*, 2013), cottonseed oil (Ghosh *et al.*, 2014), safflower oil (Abd-Elsalam and Khokhlov, 2015), coconut oil, rice bran oil (Vyas *et al.*, 2008) [labelled as Long-Chain Triglycerides (LCT), Medium-Chain Triglycerides (MCT) or Short-Chain Triglycerides (SCT) are used alone or in combination to formulate nanoemulsions, depending on their chain length. The family of D- α -tocopherols (vitamin E) has been widely used as carriers for nanoemulsions (Bernardi *et al.*, 2011; Ozturk *et al.*, 2015). Oleic acid and ethyl oleate have also been used in oral, topical, and parenteral nanoemulsions (Morais Diane and Burgess, 2014; Ali *et al.*, 2014). Efforts have been made to find a suitable marine oil (salmon oil) for emulsification purposes (Sharif Makhmalzadeh *et al.*, 2012). These marine oils are polyunsaturated. They have multiple double bonds in their structure, have multiple therapeutic benefits, and have been shown to be a safer alternative for atherosclerotic patients who cannot tolerate conventional LCTs and MCTs. The type of oil used to formulate the nanoemulsion may determine the bioavailable percentage of the active ingredient. McClements and Xiao studied the effects of shape composition and droplet size on the bioavailability of curcumin nanoemulsions (Belhaj *et al.*, 2010).

Surfactants and co-surfactants

Surfactants are amphiphilic molecules that stabilize nanoemulsions by lowering interfacial tension and preventing droplet aggregation. They tend to adsorb rapidly at the oil-water interface, providing steric or electrostatic or double-electrostatic steric stabilization. A frequently used surfactant in nanoemulsions is lecithin (phosphatidylcholine) obtained from egg yolk or soybean (McClements and Xiao, 2012). Surfactants such as sodium deoxycholate (bile salt) (Ozturk *et al.*, 2015) and Cremophor EL (polyoxyl 35 castor oil) (Klang and Valenta, 2011) are used in marketed parenteral products. Tween 20, 40, 60, and 80 (polyoxyethylene sorbitan monolaurate) (Zhang *et al.*, 2016; Wang *et al.*, 2008), Span 20, 40, 60, and 80 (sorbitan monolaurate) (Azeem *et al.*, 2009; Jo and Kwon, 2014; Polychniatou and Tzia, 2014), Solutol HS-15 (Polyoxyethylene 660 hydroxystearate) is also regularly used (Jadhav *et al.*, 2015). Other common surfactants include those belonging to the poloxamer family (Scheller *et al.*, 2014), sodium dodecyl sulphate (Brüsewitz *et al.*, 2007; Erramreddy and Ghosh, 2014), amphipathic proteins such as casein (Uluata *et al.*, 2016; He *et al.*, 2011), β -lactoglobulin

(Maher *et al.*, 2011), polysaccharides (gums, starch derivatives, etc.) (Ali *et al.*, 2016) and PEG-containing block copolymers (Combrinck *et al.*, 2014).

Preservatives, antioxidants, chemical protectants

Preservatives used in nanoemulsions must meet criteria such as low toxicity, thermal and storage stability, physical and chemical compatibility, reasonable cost, ready availability, acceptable odour, taste and color; it should have a broad antibacterial spectrum. Microorganisms thrive in both oil and water, so the preservative chosen must achieve effective concentrations in both stages. It is more or less avoided because of the acids and acid derivatives, i.e., Benzoic acid (Rapoport *et al.*, 2010), sorbic acid, propionic acid (Li *et al.*, 2014), and dehydroacetic acid (Figueroa Alvarez and Blanco-Méndez, 2001) can be used as antifungal agents in formulations. Alcohols such as chlorobutanol and phenoxy-2-ethanol are routinely used in ophthalmology. Phenols and quaternary ammonium compounds act as broad-spectrum preservatives (Hussan, 2011). Emulsified oils and lipids auto-oxidize when exposed to air. Many drugs used in nanoemulsions are also highly susceptible to oxidative degradation. Unsaturated oils stink when oxidized (Nigade *et al.*, 2012). If you want to avoid oxidation, we recommend using synthetic lipids that lack sensitive acyl groups. However, this is not always feasible, so additional ingredients are added: antioxidants. Antioxidants provide oxidative stability to formulations by either (Kumar, 2014).

Reducing agents - e.g., B. Ascorbic acid, sodium bisulfide, metabisulfite, thiourea and sodium formaldehyde or blocking agents e.g., As ascorbic acid esters, butylated hydroxytoluene

and tocopherol or synergists, e.g., Ascorbic acid, citric acid, phosphoric acid, tartaric acid.

Techniques of Nanoemulsion formulation

Numerous strategies have been utilized to define nanoemulsions, counting high-pressure homogenization, smaller scale fluidization, stage reversal, unconstrained emulsification, dissolvable vanishing, and hydrogel arrangement (Bhosale *et al.*, 2014; Jaiswal *et al.*, 2015). Numerous emulsions are commonly arranged utilizing the twofold emulsion dissolvable vanishing strategy. Different strategies have been utilized to characterize such nanoemulsions that have been utilized as sedate conveyance frameworks. Mechanisms and pathways of emulsion destabilization are shown in Figure 1.

Nanoemulsions are mainly formulated using following main methods

Persuasion/phase reversal method

The arrangement of nanoemulsions by the influence strategy does not require outside strengths and includes the arrangement of fine scatterings as stage moves happen by changing either the temperature or the composition whereas keeping the elective parameters consistent. Influence strategies can be broadly categorized as (i) stage moves from near-optimal states by means of changes in single factors, counting changing definition factors such as temperature or saltiness to near-optimal values. The ideal Hydrophilic Lipophilic Deviation (HLD) is near to middle of the road levels for frameworks that utilize higher temperatures, for case for microemulsions. (ii) stage moves from near-optimal states through alteration of numerous factors; That's, numerous detailing factors are changed. For case, applying higher temperatures and

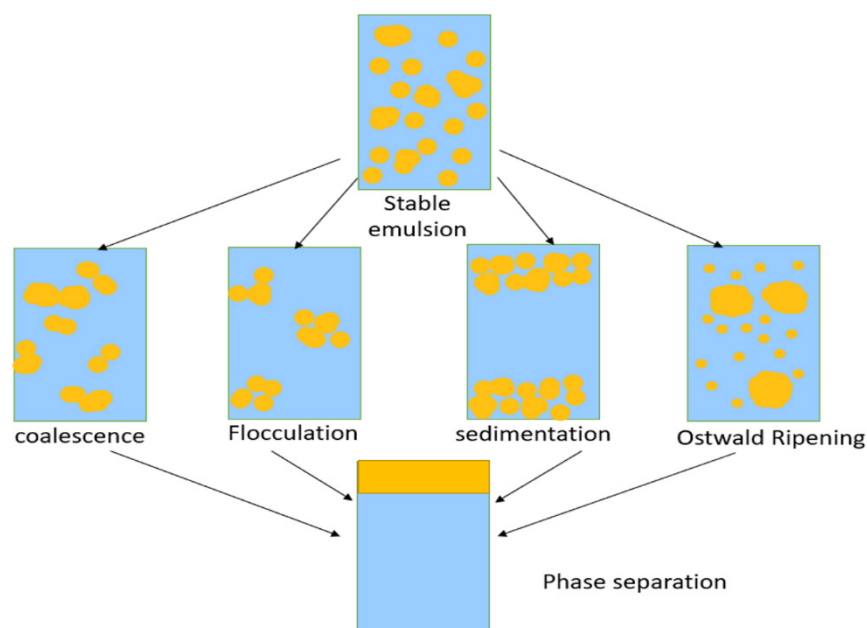


Figure 1: Emulsion destabilization mechanisms and pathways.

including additional salt within the microemulsion (Singh and Vingar, 2008; Shafiq *et al.*, 2007; Yilmaz and Borchert, 2006). (iii) Disastrous reversal, reversal of inner stage emulsions such that the inside stage changes to the outside stage. (iv) stage moves stabilized by fluid gem arrangement, counting stabilization of nanodroplets from the near-HLD-0 state by fluid precious stone arrangement (Shakeel *et al.*, 2007; Shakeel *et al.*, 2008; Klang *et al.*, 2010).

Brute force method

In this process, brute force breaks the oil droplets down to the nanoscale. Equipment that has been used to formulate nanoemulsions includes heavy-pressure homogenizers, great-speed mixers, small-pore membranes, and max-frequency ultrasonicates (Baspinar *et al.*, 2010). The characteristics of nanoemulsions such as low size, optical straightforwardness and tall dynamic steadiness depend not as it were on compositional factors but moreover on preparing factors such as emulsification time, degree of blending, vitality input and emulsification. Heavy-pressure homogenization (Schwarz *et al.*, 2012) and micro fluidization (Borhade *et al.*, 2012) methods is generally used on both industrial and laboratory scales to achieve very small nanoemulsion sizes using high-pressure equipment (Ghosh *et al.*, 2013). Various other methods, such as sonication (Zhu *et al.*, 2015) and *in situ* emulsification (Başpınar *et al.*, 2015), are also used to prepare nanoemulsions (Calligaris *et al.*, 2016; Kaur *et al.*, 2016).

High pressure homogenization

Since the arrangement of nanoemulsions requires tall shear strengths, this technique employs a high-pressure homogenizer or a cylinder homogenizer to get ready nanoemulsions with exceptionally little molecule sizes (down to 1 nm) (Meng *et al.*, 2016; Fornaguera *et al.*, 2016). In this innovation, the blend streams through an opening at exceptionally tall weights extending from 500 to 5000 psi. The coming about item is assist subjected to serious turbulence and water powered shear to deliver an emulsion of exceptionally fine particles (Chen *et al.*, 2016). In spite of the fact that this has demonstrated to be the foremost proficient strategy for planning nanoemulsions, the as it were downsides related with this strategy are the tall vitality utilization and temperature rise of the emulsion amid preparing. To get smaller particle sizes, it is additionally vital to run bigger homogenization cycles. Ilmaz *et al.* arranged Phyto sphingosine o/w nanoemulsions utilizing high-pressure homogenization strategy, the bead measure diminished after 8 cycles of homogenization, and he found that such nanoemulsions were steady for 6 months (Yilmaz and Borchert, 2005; Uluata *et al.*, 2016; Goh *et al.*, 2015).

Micro Fluidization

This strategy utilized a gadget known as a microfluidizer, which employs a high-pressure relocation pump (500-20,000 psi) to constrain the item through an interaction chamber of stainless-steel microchannels within the contact zone, creating exceptionally little sub-particles. The blend is over and over circulated through the microfluidizer until the required molecule estimate is come to. The coming about item is additionally passed through a channel to isolated littler beads from bigger ones and create a uniform nanoemulsion. Uluata *et al.* arranged O/W nanoemulsions of octadecane employing a microfluidizer and found that the bead measure diminished as the number of passes and homogenization weight expanded (Shi *et al.*, 2015).

Spontaneous Emulsification

This strategy included the arrangement of a nanoemulsion in 3 steps. The primary step included shaping a natural arrangement containing oil and lipophilic surfactant in a water-miscible solvent and hydrophilic surfactant and after that shaping an O/W emulsion by infusing that natural stage into the hydrophilic stage beneath attractive blending. The natural dissolvable was at that point evacuated in a third step by dissipation. Sugumar *et al.* arranged a steady eucalyptus oil nanoemulsion by unconstrained emulsion and the normal bead estimate was found to be between 50 and 100 nm (Sugumar *et al.*, 2015).

Solvent Evaporation Technique\Hydrogel Method

In this method, a medicate arrangement is ready and emulsified in another fluid (not the sedate dissolvable), at that point the dissolvable is dissipated, coming about in precipitation of the medicate. High-speed mixing can be utilized to control precious stone development and molecule conglomeration. The hydrogel strategy is exceptionally comparable to the dissolvable dissipation strategy. The as it were contrast from the dissolvable dissipation strategy is that in this case the medicate arrangement is blended with the sedate antisolvent (Table 1) (Bhagav *et al.*, 2011).

Identification of Nanoemulsions

Recent advancements in delivery of nanoemulsion drug

The purpose of an optimum DDS is supposed to maximise therapeutic benefit while reducing harm. The emulsified oil and water systems that make up nanoemulsions, which have mean of diameter of droplet ranging from 50 to 1000 nm, are new medication delivery methods. In order to administer medications that are poorly water-soluble effectively, a variety of innovative techniques are currently being developed nowadays as shown in Table 2.

Table 1: Different identification techniques for nanoemulsions.

Characterization Technique's	Description
Encapsulation Efficiency	Drug content is estimated by spectrophotometric analysis of the extract at the $\lambda_{\max}$ of the drug after making appropriate dilutions against appropriate blanks.
Particle size and Polydispersity Index (PDI) measurements	Particle size and PDI of nanoemulsions are analysed using Photon Correlation Spectroscopy (PCS) using a Malvern Zetasizer to monitor changes in light scattering due to Brownian motion of particles as a function of time (Baboota <i>et al.</i> , 2007).
Determination of Zeta Potential	To calculate the zeta potential, the nanoemulsion was diluted and its value is calculated from the electrophoretic mobility of the oil droplets. A zeta potential of ± 30 mV is probably sufficient to ensure the physical stability of the Nanoemulsion (Đorđević <i>et al.</i> , 2015).
Fourier-Transform Infrared Spectroscopy (FTIR)	FTIR can be performed to find drug excipient interactions, polymerization, crosslinking, and drug loading in a formulation. It is also used to identify functional groups through their attachment and molecular fingerprinting (Srilatha <i>et al.</i> , 2013).
Morphological study of nanoemulsion	The study of Nanoemulsion for its morphological properties is performed by the use of a Transmission Electron Microscope (TEM). To perform TEM, a few drops of nanoemulsion or suspension of lyophilized nanoparticles in double distilled water are prepared and placed on a perforated membrane grid and immobilized (Bali <i>et al.</i> , 2010).
Atomic Force Microscope (AFM)	AFM is performed by diluting the nanoemulsion with water and then drop coating the diluted nanoemulsion onto a glass slide (Karthikeyan <i>et al.</i> , 2012; Drais and Hussein, 2015)
Dispersibility studies	Dispersibility studies to evaluate the efficiency of self-emulsification of nanoemulsions are performed using standard USP XXII dissolution equipment (Kotta <i>et al.</i> , 2014)
Viscosity measurement	Viscosity evaluation is an important parameter for the physicochemical characterization of nanoemulsions. A variety of instruments are used to measure viscosity, including Ostwald viscometers, Hepler falling ball viscometers, Stormer viscometers, Brookfield viscometers (Kuo <i>et al.</i> , 2008; Harwansh <i>et al.</i> , 2011; Malik <i>et al.</i> , 2014)
Refractive index	The refractive index (n) of a medium can be defined as the ratio of the wave velocity (c) in the reference medium to the wave phase velocity (vp) in the medium (Harika <i>et al.</i> , 2015; Gué <i>et al.</i> , 2016).
Measurement of pH and osmolarity	The pH meter is utilized to degree the pH of a nanoemulsion and to decide the osmolarity of an emulsion with a smaller scale osmometer utilizing the solidifying point strategy (Morsi <i>et al.</i> , 2014)

Applications of nanoemulsions

Parenteral Delivery

Nanoemulsion has points of interest for intravenous organization due to the strict necessities of this course of organization, particularly the require for the bead estimate of the definition to be less than 1 small scale meter. Parenteral (or injectable) organization of nanoemulsion is utilized for a few purposes, specifically sustenance, such as fats, carbohydrates, vitamins, etc. Nanoemulsion details have unmistakable preferences over macroemulsion frameworks for parenteral organization, as nanoemulsion clears more gradually than coarse molecule emulsion and thus. incorporates a longer home time within the body. Both O/W and W/O nanoemulsion can be utilized for parenteral organization.

Oral administration

Nanoemulsion definitions have numerous preferences over ordinary verbal definitions, counting expanded retention, progressed clinical viability, and decreased sedate harmfulness.

In this way, nanoemulsion demonstrates to be perfect for conveyance of drugs such as steroids, hormones, diuretics and anti-microbials. Peptide and protein drugs are exceedingly viable and particular in their physiological capacities. Primaquine combined with a verbal lipid nanoemulsion appeared viable antimalarial action against *Plasmodium berghei* contamination in mice at a 25% lower dosage compared to a ordinary verbal measurements. Lipid nanoemulsion of primaquine progressed verbal bioavailability within the liver, with sedate concentrations at slightest 5% higher compared to immaculate sedate.

Local administration

Neighbourhood organization of drugs can have focal points over other strategies for a few reasons, one of which is evasion of first-pass digestion system within the liver and related harmful impacts. Another is to straightforwardly dosage and coordinate the medicate to the influenced skin or eye range. Nanoemulsion can accomplish a tall topical antimicrobial impact, which was already as it were accomplished with systemic anti-microbials. Nanoemulsion contains a wide range of movement against

Table 2: Recent advancements in delivery of nanoemulsion drug.

Routes of administration	Methods/Materials	Treatment	References
Ocular drug delivery Tamoxifen	Water titration technique (oleic acid, tween 80 or tween 20 and PEG400).	Photoreceptor degeneration disorder.	(Aboumanei and Mahmoud, 2022)
Isoliquiritigenin (ISL)	Pseudo ternary phase diagrams (PEG400, Propylene Glycol Dicaprylate (PGD), Cremophor EL).	Treatment of Corneal Neovascularization (CNV).	(Zhang <i>et al.</i> , 2022)
Celecoxib	Pseudo ternary phase diagrams by titration method (Tween 80, propylene glycol, oleic acid).	Rheumatoid arthritis and osteoarthritis, analgesic.	(Salimi and Moghimipour, 2017)
Brinzolamide	Spontaneous emulsification method (Triacetin, labrasol, cremophore, capryol90).	Ocular hypertension	(Mahboobian <i>et al.</i> , 2017)
Situ Ocular gel of diclofenac sodium	Pseudo ternary phase diagram (Oleic acid, Tween 20, Ethanol, poloxamer 407).	Improving corneal penetration	(Chauhan and Batra, 2018)
Oral drug delivery Letrozole	Simple titration method (Oleic acid, tween 80, olive oil, sesame oil).	Breast cancer.	(Alhamdany <i>et al.</i> , 2021)
Fenofibrate	Pseudo ternary phase diagram by hydrophilic titration method (Tween80, PEG400, methanol).	Hypolipidemic agent	(Gulati <i>et al.</i> , 2021)
Felodipine	Pseudo ternary phase diagram by hydrophilic titration method (Tween 80, tween 60, ethanol).	Blood pressure and angina pectoris.	(Hamed and Abd Alhammid, 2021)
Montelukast sodium	Ultra-sonication method (Tween 20, tween 40, tween 60, tween 80, propylene glycol, PEG400, Oleic acid, clove oil).	Asthma and seasonal allergies.	(Almajidi and Mahdi, 2018)
Exenatide (Peptide)	Hydrophilic titration method (Tween 80, capric acid, span 80)	Antidiabetic	(Lin <i>et al.</i> , 2019)
Carvedilol	Hydrophilic phase titration method (Tween 20, PEG 200, PEG 400, PEG 600, Castor oil, span 60).	Congestive heart failure and hypertension.	(Chidi <i>et al.</i> , 2017)
Intravenous drug delivery 4-(chloromethyl)-3-nitro-N-(2-hydroxyethyl) benzamide (CNB)	Hot melting homogenization method (Tween 80, glycerol, sesame oil, soybean lecithin).	Cancer	(Duarte <i>et al.</i> , 2019)
Rifampicin	Hydrophilic phase titration method (Tween 80, tween 85, sefsol 218).	Antitubercular	(Ahmed <i>et al.</i> , 2008)
Nimodipine	Simple hydrophilic solubility method (Methanol, heparin sodium salt, diethyl ether, acetonitrile).	Ischemic cerebrovascular and Alzheimer's disease.	(Huang <i>et al.</i> , 2020)
Carvedilol	Ultrasonication method (Tween 80, oleic acid, PEG 400, methanol, NaOH).	Antihypertensive	(Kumar <i>et al.</i> , 2018)
Intranasal drug delivery Tetrabenazine	Pseudo ternary phase diagrams using hydrophilic titration method (Tween 20, tween 80, labrasol, transcutoil, acetonitrile).	Huntington's disease	(Arora <i>et al.</i> , 2020)
Sumatriptan (SMT)	Hydrophilic phase titration method (Tween 20, tween 80, copaiba oil, pectin).	Migraine	(Ribeiro <i>et al.</i> , 2020)

Routes of administration	Methods/Materials	Treatment	References
Vitamin E loaded Naringenin	Hydrophilic titration method (Caproyl 90, PEG 400, Tween 80, captex 200, olive oil).	Parkinson's disease	(Gaba <i>et al.</i> , 2019)
Almotriptan	Titration method (Oleic acid, tween 20, carbitol, polyethylene sorbitan monolaurate).	Headache, nausea	(Wagh and Mane, 2022)
Zolmitriptan	Ultra-sonication method which is high energy method (Caproyl PGMC, Captex 200, Polyoxyl 40, castor oil).	Migraine	(Abdou <i>et al.</i> , 2017)
Rizatriptan benzoate	Pseudo ternary phase diagram (Oleic acid, Tween 20, sesame oil, tween 80, olive oil).	Migraine, headache	(Hadi and Ghareeb, n.d.)
Topical drug delivery 8-methoxypsoralen	High pressure homogenization method (Cremophor RH 40, PEG 40, hydrogenated castor oil, chitosan).	Skin disease such as vitiligo and psoriasis.	(Barradas <i>et al.</i> , 2018)
Daidzein	High pressure homogenization technique (ethyl oleate, Tween 80, dimethyl sulfoxide, sodium dodecyl sulfate, isopropyl alcohol, methanol).	Antioxidant and anti-inflammatory exercises and hinder development of cancer cells.	(Kaplan <i>et al.</i> , 2019)
Econazole nitrate	Spontaneous emulsification method (Oleic acid, PEG 200, Tween 20).	Skin and fungal disease.	(Shaikh <i>et al.</i> , 2019)
Febuxostat	High speed homogenization technique (isopropyl myristate, span 80, Tween 80).	Hyperuricemia, Gout	(Reddy and Sundari, 2019)
Flucinolone-acetonide	Pseudo ternary phase diagram by hydrophilic dilution method, ultra-sonication method (Oleic acid, Tween 20, PEG 400).	Reduce inflammation of skin	(Katyan <i>et al.</i> , 2022)
Rifampicin	Sonication method (Benzoic acid, oleic acid, Tween 80, salicylic acid).	Bacterial and fungal infections of skin	(Begum <i>et al.</i> , 2019)

microscopic organisms (e.g., *E. coli*, *S. aureus*) and parasites (e.g., Candida, Dermatophytes) (Vyas *et al.*, 2008; Tamilvanan, 2004).

Cosmetics

The stylish properties of Nanoemulsion, i.e., moo thickness and straightforward visual angles when the beads are underneath 200 nm, its huge surface, which permits the viable transport of the dynamic fixing to the skin, makes them especially appealing for utilize in beauty care products. Nanoemulsions are worthy in beauty care products since macroemulsions don't show normal creaming, sedimentation, flocculation or coalescence. The expansion of possibly chafing surfactants can be maintained a strategic distance from by utilizing high-energy hardware amid generation. Nanogel innovation makes a mini-emulsion from an oil-in-water concentration that is reasonable for minimizing trans epidermal water misfortune, upgrading skin assurance and entrance of the dynamic fixing. It would be valuable in sun care items, moisturizers, and anti-aging creams. This makes a difference skin care items feel great on the skin (Heidi *et al.*, 2009).

Transdermal

The anti-inflammatory impact of a genuine optimized nanoemulsion definition of the strong NSAID indomethacin was compared with a showcased gel on carrageenan-induced paw edema in rats. The restraint rate was critical for the created nanoemulsion, so it has awesome potential for transdermal utilize of indomethacin. Nanoemulsions for transdermal organization of celecoxib, a detailing comprising of 2-lectoxib in 10% oil stage (Sefsol 218 and Triacetin), 50% surfactant blend (Tween 80 and Transcutol-P) and 0% water. The anti-inflammatory movement and hindrance rate after 2 hr of organization were found to be tall for the nanoemulsion detailing (81.2%) compared to celecoxib gel (3.7%) and nanoemulsion gel (6 .5%). Considers *in vitro* and *in vivo* appeared a noteworthy increment within the anti-inflammatory impact of aceclofenac nanoemulsion (82.2%) compared to nanoemulsion gel (71. %) and customary gel (1.8%).

Cancer therapy Nanoemulsion can be utilized as a carrier for cancer chemotherapy to extend the rate of medicate discharge after intramuscular and intertumoral infusion (W/O frameworks). It too increments the transport of transdermal drugs since the

transport of anticancer drugs is expanded through the skin through the lymph nodes and it is additionally a non-irritant framework.

Intranasal drug delivery

In expansion to parenteral and verbal courses of organization, intranasal sedate conveyance frameworks are presently recognized as a solid strategy of regulating drugs. The nasal mucosa has developed as a remedially practical channel for systemic medicate conveyance additionally shows up to be a helpful way to overcome boundaries to direct sedate section to target destinations. is additionally easy, non-invasive and well tolerated. The nasal depression is one of the foremost productive locales due to its decreased enzymatic movement, tall accessibility of immunologically dynamic locales, and tolerably penetrable epithelium. There are a few issues related with focusing on the brain of drugs, particularly those with hydrophilic and tall atomic weights. This can be due to the impermeability of the endothelium, which isolates the systemic circulation and obstruction between blood and brain. The olfactory locale of the nasal mucosa gives a coordinate association between the nose and the brain, and drug-laden nanoemulsions can be utilized to treat Alzheimer's malady, headaches, discouragement, schizophrenia, Parkinson's malady, meningitis, etc. maladies can be treated. The arrangement of nanoemulsions containing risperidone for nasal conveyance to the brain has been detailed. It was concluded that this emulsion is more successful through the nasal course than through the intravenous course. Another application of intranasal medicate conveyance frameworks in treatment is their utilize in antibody advancement. Immunization is accomplished by organization of mucosal antigens. The primary intranasal immunization has fair been propelled. Among the conceivable conveyance systems, the utilize of nano-based carriers guarantees to secure biomolecules, encourage interaction of nanocarriers with mucosa, and target antigens to lymphoid tissues. In this manner, the utilize of nanoemulsions in intranasal drug conveyance systems within the treatment of illnesses related with the central anxious framework will have vital results in focusing on drugs to the brain. We have created intranasal nanoemulsion and gel details of rizatriptan benzoate for long-term activity. Different mucoadhesive specialists have been attempted to frame heat-induced mucoadhesive nanoemulsions.

Pulmonary drug delivery

The lungs are well-suited for non-invasive organization by means of breathed in pressurized canned products, evasion of first-pass digestion system, coordinate conveyance to the location of activity to treat respiratory infections, and accessibility of a tremendous surface zone for localized sedate conveyance. It could be a major target for medicate conveyance. Therapeutic viability and systemic retention of drugs. Colloidal carriers (i.e.,

nanocarrier frameworks) in pneumonic sedate conveyance offer numerous focal points, such as decreased dosing recurrence, moved forward persistent compliance, decreased rate of side impacts, and potential sedate take-up by cells (Heidi *et al.*, 2009).

CONCLUSION

Nanoemulsion drug delivery systems effectively overcome the low bioavailability drawback associated with hydrophobic drugs and food components with high first pass metabolism. There are various techniques that are used in the formulation of nanoemulsions which includes persuasion, brute force method, sonication techniques, homogenization. Formulations can be characterised by PDI, Zeta potential, FTIR, stability studies, AFM, morphological studies. In order to administer medications that are poorly water-soluble effectively, a variety of innovative techniques are currently being developed recently. Instability limits the applications of nanoemulsions. Deciding factors such as the type and conc. of surfactant and co-surfactant, the variety of oil phase, the technique used, process variables, and the mixing of additives used for the interphases of nanoemulsion formulation can improve formulation stability.

ABBREVIATIONS

NDDS: Novel Drug Delivery System; **O/W:** Oil-in-Water; **W/O:** Water-in-Oil; **LCT:** Long-Chain Triglycerides; **MCT:** Medium-Chain Triglycerides; **SCT:** Short-Chain Triglycerides; **D- α -tocopherols:** Vitamin E; **HLD:** Hydrophilic Lipophilic Deviation; **PDI:** Polydispersity Index; **PCS:** Photon Correlation Spectroscopy; **FTIR:** Fourier-Transform Infrared Spectroscopy; **TEM:** Transmission Electron Microscope; **AFM:** Atomic Force Microscope; **DDS:** Drug Delivery System; **ISL:** Isoliquiritigenin; **CNV:** Corneal Neovascularization; **CNB:** 4-(chloromethyl)-3-nitro-N-(2-hydroxyethyl) benzamide; **SMT:** Sumatriptan; **NSAID:** Non-Steroidal Anti-Inflammatory Drug.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

- Abd-El salam, K. A., & Khokhlov, A. R. (2015). Eugenol oil nanoemulsion: Antifungal activity against *Fusarium oxysporum* f. sp. *vasinfectum* and phytotoxicity on cottonseeds. *Applied Nanoscience*, 5(2), 255-265. <https://doi.org/10.1007/s13204-014-0398-y>
- Abdou, E. M., Kandil, S. M., & Miniawy, H. M. F. E. (2017). Brain targeting efficiency of antimigrain drug loaded mucoadhesive intranasal nanoemulsion. *International Journal of Pharmaceutics*, 529(1-2), 667-677. <https://doi.org/10.1016/j.ijpharm.2017.07.030>
- Aboofazeli, R. (2010). Nanometric-Scaled Emulsions (nanoemulsions), Iran. *Iranian Journal of Pharmaceutical Research*, 9(4), 325-326.
- Aboumanei, M. H., & Mahmoud, A. F. (2022). Development of tamoxifen *in situ* gel nanoemulsion for ocular delivery in photoreceptor degeneration disorder: *In vitro* characterization, 131I-radiolabeling, and *in vivo* biodistribution studies. *Journal of Pharmaceutical Innovation*, 18(2), 369-380. <https://doi.org/10.1007/s12247-022-09638-w>
- Ahmed, M., Ramadan, W., Rambhu, D., & Shakeel, F. (2008). Potential of nanoemulsions for intravenous delivery of rifampicin. *Die Pharmazie*, 63(11), 806-811. <https://doi.org/10.31083/ph.2008.8108>

- Al-Edresi, S., & Baie, S. (2009). Formulation and stability of whitening VCO-in-water nano-cream. *International Journal of Pharmaceutics*, 373(1-2), 174-178. <https://doi.org/10.1016/j.ijpharm.2009.02.011>
- Ali, G., Mekhloufi, N. H., & Agnely, F. (2016). Beta-lactoglobulin stabilized nanemulsions-Formulation and process factors affecting droplet size and nanoemulsion stability. *International Journal of Pharmacy*, 500(1-2), 291-304.
- Ali Khan, A. A., Mudassir, J., Mohtar, N., & Darwis, Y. (2013). Advanced drug delivery to the lymphatic system: Lipid-based nanoformulations. *International Journal of Nanomedicine*, 8, 2733-2744. <https://doi.org/10.2147/IJN.S41521>
- Ali, M. S., Alam, M. S., Alam, N., & Siddiqui, M. R. (2014). Preparation, characterization and stability study of dutasteride loaded nanoemulsion for treatment of benign prostatic hypertrophy. *Iranian Journal of Pharmaceutical Research*, 13(4), 1125-1140.
- Almajidi, Y. Q., Mahdi, Z. H., & Maraie, N. K. (2018). Preparation and *in vitro* evaluation of montelukast sodium oral nanoemulsion. *International Journal of Applied Pharmaceutics*, 10(5), 49. <https://doi.org/10.22159/ijap.2018v10i5.28367>
- Alvarez-Figueroa, M. J., & Blanco-Méndez, J. (2001). Transdermal delivery of methotrexate: Iontophoretic delivery from hydrogels and passive delivery from microemulsions. *International Journal of Pharmaceutics*, 215(1-2), 57-65. [https://doi.org/10.1016/S0378-5173\(00\)00674-8](https://doi.org/10.1016/S0378-5173(00)00674-8)
- Amani, A., York, P., Chrystyn, H., & Clark, B. J. (2010). Evaluation of a nanoemulsion-based formulation for respiratory delivery of budesonide by nebulizers. *AAPS PharmSciTech*, 11(3), 1147-1151. <https://doi.org/10.1208/s12249-010-9486-9>
- Ammar, H. O., Salama, H. A., Ghorab, M., & Mahmoud, A. A. (2009). Nanoemulsion as a potential ophthalmic delivery system for dorzolamide hydrochloride. *AAPS PharmSciTech*, 10(3), 808-819. <https://doi.org/10.1208/s12249-009-9268-4>
- Anuchapreeda, S., Fukumori, Y., Okonogi, S., & Ichikawa, H. (2012). Preparation of lipid nanoemulsions incorporating curcumin for cancer therapy. *Journal of Nanotechnology*, 2012(1), 1-11. <https://doi.org/10.1155/2012/270383>
- Arora, A., Kumar, S., Ali, J., & Baboota, S. (2020). Intranasal delivery of tetrabenazine nanoemulsion via olfactory region for better treatment of hyperkinetic movement associated with Huntington's disease: Pharmacokinetic and brain delivery study. *Chemistry and Physics of Lipids*, 230, 104917. <https://doi.org/10.1016/j.chemphyslip.2020.104917>
- Aulton, M. E., & Taylor, K. M. (2013). Aulton's pharmaceutics: The design and manufacture of medicines. Elsevier Health Sciences.
- Azeem, A., Rizwan, M., Ahmad, F. J., Iqbal, Z., Khar, R. K., Aqil, M., & Talegaonkar, S. (2009). Nanoemulsion components screening and selection: A technical note. *AAPS PharmSciTech*, 10(1), 69-76. <https://doi.org/10.1208/s12249-008-9178-x>
- Baboota, S., Shakeel, F., Ahuja, A., Ali, J., & Shafiq, S. (2007). Design, development and evaluation of novel nanoemulsion formulations for transdermal potential of celecoxib. *Acta Pharmaceutica*, 57(3), 315-332. <https://doi.org/10.2478/v10007-007-0025-5>
- Bali, V., Ali, M., & Ali, J. (2010). Study of surfactant combinations and development of a novel nanoemulsion for minimising variations in bioavailability of ezetimibe. *Colloids and Surfaces. B, Biointerfaces*, 76(2), 410-420. <https://doi.org/10.1016/j.colsurfb.2009.11.021>
- Barradas, Thaís Nogueira, Juliana Perdiz Senna, Stephani Araujo Cardoso, K. Gyselle de Holanda e Silva, and Claudia
- Barradas, Thaís Nogueira, Juliana Perdiz Senna, Stephani Araujo Cardoso, K. Gyselle de Holanda e Silva, and c. Ç., & Karasulu, E. (2015). Pitavastatin-containing nanoemulsions: Preparation, characterization and *in vitro* cytotoxicity. *Journal of Drug Delivery Science and Technology*, 29, 117-124.
- Baspinar, Y., Keck, C. M., & Borchert, H.-H. (2010). Development of a positively charged prednicarbate nanoemulsion. *International Journal of Pharmaceutics*, 383(1-2), 201-208. <https://doi.org/10.1016/j.ijpharm.2009.09.002>
- Begum, K., Shahid, M. S., & Jalil, R. U. (2019). Topical nanoemulsion of rifampicin with benzoic acid and salicylic acid: Activity against *Staphylococcus aureus*, *Staph. epidermis* and *Candida albicans*. *Bangladesh Pharmaceutical Journal*, 22(1), 1-6. <https://doi.org/10.3329/bpj.v22i1.40018>
- Belhaj, N., Arab-Tehrany, E., & Linder, M. (2010). Oxidative kinetics of salmon oil in bulk and in nanoemulsion stabilized by marine lecithin. *Process Biochemistry*, 45(2), 187-195. <https://doi.org/10.1016/j.procbio.2009.09.005>
- Bernardi, D. S., Pereira, T. A., Maciel, N. R., Bortoloto, J., Viera, G. S., et al. (2011). Formation and stability of oil-in-water nanoemulsions containing rice bran oil: *In vitro* and *in vivo* assessments. *Journal of Nanobiotechnology*, 9(1), 44. <https://doi.org/10.1186/1477-3155-9-44>
- Bhagav, P., Upadhyay, H., & Chandran, S. (2011). Brimonidine tartrate Eudragit long-acting nanoparticles: Formulation, optimization, *in vitro* and *in vivo* evaluation. *AAPS PharmSciTech*, 12(4), 1087-1101. <https://doi.org/10.1208/s12249-011-9675-1>
- Bhanushali, R. S., Gatne, M. M., Gaikwad, R. V., Bajaj, A. N., & Morde, M. A. (2009). Nanoemulsion-based intranasal delivery of antimigraine drugs for nose to brain targeting. *Indian Journal of Pharmaceutical Sciences*, 71(6), 707-709.
- Bhosale, R. R., Osmani, R. A., Ghodake, P. P., Shaikh, S. M., & Chavan, S. R. (2014). Nanoemulsion: A review on novel profusion in advanced drug delivery. *Indian Journal of Pharmaceutical and Biological Research*, 2(1), 122-127. <https://doi.org/10.30750/ijpbr.2.1.19>
- Borhade, V., Pathak, S., Sharma, S., & Patravale, V. (2012). Clotrimazole nanoemulsion for malaria chemotherapy. Part I: Preformulation studies, formulation design and physicochemical evaluation. *International Journal of Pharmaceutics*, 431(1-2), 138-148. <https://doi.org/10.1016/j.ijpharm.2011.12.040>
- Brüsewitz, C., Schendler, A., Funke, A., Wagner, T., & Lipp, R. (2007). Novel poloxamer-based nanoemulsions to enhance the intestinal absorption of active compounds. *International Journal of Pharmaceutics*, 329(1-2), 173-181. <https://doi.org/10.1016/j.ijpharm.2006.08.022>
- Calligaris, S., Plazzotta, S., Bot, F., Grasselli, S., Malchiodi, A., & Anese, M. (2016). Nanoemulsion preparation by combining high pressure homogenization and high power ultrasound at low energy densities. *Food Research International*, 83, 25-30. <https://doi.org/10.1016/j.foodres.2016.01.033>
- Chandrasekaran, N., Sugumar, S., & Mukherjee, A. (2015). Nanoemulsion formation and characterization by spontaneous emulsification: Investigation of its antibacterial effects on *Listeria monocytogenes*. *Asian Journal of Pharmaceutics*, 9(1), 23-28. <https://doi.org/10.4103/0973-8398.150033>
- Chauhan, S., & Batra, S. (2018). Development and *in vitro* characterization of nanoemulsion embedded thermosensitive *in situ* ocular gel of diclofenac sodium for sustained delivery. *International Journal of Pharmaceutical Sciences and Research*, 9(6), 2301-2314.
- Chen, H., Hu, X., Chen, E., Wu, S., McClements, D. J., et al. (2016). Preparation, characterization, and properties of chitosan films with cinnamaldehyde nanoemulsions. *Food Hydrocolloids*, 61, 662-671. <https://doi.org/10.1016/j.foodhyd.2016.06.034>
- Chidi, E., E. I. N., Zainab, A., & John, D. F. *Development and evaluation of nanoemulsion*.
- Combrinck, J., Otto, A., & du Plessis, J. (2014). Whey protein/polysaccharide-stabilized emulsions: Effect of polymer type and pH on release and topical delivery of salicylic acid. *AAPS PharmSciTech*, 15(3), 588-600. <https://doi.org/10.1208/s12249-014-0081-3>
- Đorđević, S. M., Cekić, N. D., Savić, M. M., Isailović, T. M., Randelović, D. V., et al. (2015). Parenteral nanoemulsions as promising carriers for brain delivery of risperidone: Design, characterization and *in vivo* pharmacokinetic evaluation. *International Journal of Pharmaceutics*, 493(1-2), 40-54. <https://doi.org/10.1016/j.ijpharm.2015.07.007>
- Drais, H. K., & Hussein, A. A. (2015). Formulation and characterization of carvedilol nanoemulsion oral liquid dosage form. *International Journal of Pharmacy and Pharmaceutical Sciences*, 7(12), 209-216.
- Duarte, J. A., Pereira, N. C., de Oliveira, J. T., de Barros, A. L. B., Dos Santos, F. V., et al. (2019). Nanoemulsion system for intravenous administration of bioactive nitroaromatic compound reduces genotoxicity and increases tumor uptake in murine experimental model. *Journal of Drug Delivery Science and Technology*, 53, 101161. <https://doi.org/10.1016/j.jddst.2019.101161>
- Ensign, L. M., Cone, R., & Hanes, J. (2012). Oral drug delivery with polymeric nanoparticles: The gastrointestinal mucus barriers. *Advanced Drug Delivery Reviews*, 64(6), 557-570. <https://doi.org/10.1016/j.addr.2011.12.009>
- Erramreddy, V. V., & Ghosh, S. (2014). Influence of emulsifier concentration on nanoemulsion gelation. *Langmuir*, 30(37), 11062-11074. <https://doi.org/10.1021/la502733v>
- Formulations for improved oral delivery of carvedilol. (2017). *Universal Journal of Pharmaceutical Research*, 2(1).
- Formulations of antihypertensive drug carvedilol. (2018). *European Journal of Molecular and Clinical Medicine (EJMCM)*, 5(01).
- Fornaguera, C., Feiner-Gracia, N., Calderó, G., García-Celma, M. J., & Solans, C. (2016). PLGA nanoparticles from nano-emulsion templating as imaging agents: Versatile technology to obtain nanoparticles loaded with fluorescent dyes. *Colloids and Surfaces. B, Biointerfaces*, 147, 201-209. <https://doi.org/10.1016/j.colsurfb.2016.08.001>
- Gaba, B., Khan, T., Haider, M. F., Alam, T., Baboota, S., Parvez, S., & Ali, J. (2019). Vitamin E loaded naringenin nanoemulsion via intranasal delivery for the management of oxidative stress in a 6-OHDA Parkinson's disease model. *BioMed Research International*, 2019(1), 2382563. <https://doi.org/10.1155/2019/2382563>
- Garti, N., Frenkel, M., & Schwartz, R. (1983). Multiple emulsions. Part I: Proposed technique to overcome unpleasant taste of drugs. *Journal of Dispersion Science and Technology*, 4(3), 237-252. <https://doi.org/10.1080/01932698308943369>
- Ghosh, V., Mukherjee, A., & Chandrasekaran, N. (2013). Ultrasonic emulsification of food-grade nanoemulsion formulation and evaluation of its bactericidal activity. *Ultrasonics Sonochemistry*, 20(1), 338-344. <https://doi.org/10.1016/j.ultsonch.2012.08.010>
- V. Ghosh, A. Mukherjee, N. Chandrasekaran, Eugenol-loaded antimicrobial nanoemulsion preserves fruit juice against microbial spoilage, *Colloids Surf. B Bio interfaces* 114 (2014) 392–397.
- Goh, P. S., Ng, M. H., Choo, Y. M., Amru, N. B., & Chuah, C. H. (2015). Production of nanoemulsions from palm-based tocotrienol rich fraction by microfluidization. *Molecules*, 20(11), 19936-19946. <https://doi.org/10.3390/molecules201119666>
- Gué, E., Since, M., Ropars, S., Herbinet, R., Le Pluart, L., & Malzert-Fréon, A. (2016). Evaluation of the versatile character of a nanoemulsion formulation. *International Journal of Pharmaceutics*, 498(1-2), 49-65. <https://doi.org/10.1016/j.ijpharm.2015.12.010>
- Gulati, N., Kumar Chellappan, D., Tambuwala, M., A A Aljabali, A., Prasher, P., et al. (2021). Oral nanoemulsion of fenofibrate: Formulation, characterization, and *in vitro* drug release studies. *Assay and Drug Development Technologies*, 19(4), 246-261. <https://doi.org/10.1089/adt.2021.012>

- Hadi, A. S., & Ghareeb, M. M. (2022). *Rizatriptan benzoate nanoemulsion for intranasal drug delivery: Preparation and characterization*, 12 (2), 546-552.
- Hamed, B. Sumaya and Shaimaa N. Abd Alhammid. (2021). *Formulation and characterization of felodipine as an oral nanoemulsions*, 30(1), 209-217.
- Harika, K., Debnath, S., & Babu, M. N. (2015). Formulation and evaluation of nanoemulsion of amphotericin B. *IJNTPS*, 5(4), 114-122.
- Harwansh, R. K., Patra, K. C., Pareta, S. K., Singh, J., & Rahman, M. A. (2011). Nanoemulsions as vehicles for transdermal delivery of glycyrrhizin. *Brazilian Journal of Pharmaceutical Sciences*, 47(4), 769-778. <https://doi.org/10.1590/S1984-82502011000400014>
- He, W., Tan, Y., Tian, Z., Chen, L., Hu, F., & Wu, W. (2011). Food protein-stabilized nanoemulsions as potential delivery systems for poorly water-soluble drugs: Preparation, in vitro characterization, and pharmacokinetics in rats. *International Journal of Nanomedicine*, 6, 521-533. <https://doi.org/10.2147/IJN.S17282>
- Huang, S., Huang, Z., Fu, Z., Shi, Y., Dai, Q., et al. (2020). A novel drug delivery carrier comprised of nimodipine drug solution and a nanoemulsion: Preparation, characterization, in vitro, and in vivo studies. *International Journal of Nanomedicine*, 15, 1161-1172. <https://doi.org/10.2147/IJN.S226591>
- Hussain, A., Samad, A., Singh, S. K., Ahsan, M. N., Haque, M. W., et al. (2016). Nanoemulsion gel-based topical delivery of an antifungal drug: In vitro activity and in vivo evaluation. *Drug Delivery*, 23(2), 642-647. <https://doi.org/10.3109/10717544.2014.933284>
- Hwang, Y. Y., Ramalingam, K., Bienek, D. R., Lee, V., You, T., & Alvarez, R. (2013). Antimicrobial activity of nanoemulsion in combination with cetylpyridinium chloride in multidrug resistant *Acinetobacter baumannii*. *Antimicrobial Agents and Chemotherapy*, 57(8), 3568-3575. <https://doi.org/10.1128/AAC.02109-12>
- Jadhav, V. K., & Payghan, S. A. (2015). Investigation of effect of non-ionic surfactant on preparation of griseofulvin non-hydrophilic nanoemulsion. *J. Nanostruct. Chem.*, 5(1), 107-113.
- Jaiswal, M., Dudhe, R., & Sharma, P. K. (2015). Nanoemulsion: An advanced mode of drug delivery system. 3 *Biotech*, 5(2), 123-127. <https://doi.org/10.1007/s13205-014-0214-0>
- Jiang, S.-P., He, S.-N., Li, Y.-L., Feng, D.-L., Lu, X.-Y., et al. (2013). Preparation and characteristics of lipid nanoemulsion formulations loaded with doxorubicin. *International Journal of Nanomedicine*, 8, 3141-3150. <https://doi.org/10.2147/IJN.S47708>
- Jo, Y.-J., & Kwon, Y.-J. (2014). Characterization of β -carotene nanoemulsions prepared by microfluidization technique. *Food Science and Biotechnology*, 23(1), 107-113. <http://doi.org/10.1007/s10068-014-0014-7>
- Kaplan, A. B. Ugur, Meltem Cetin, Dilara Orgul, Ali Taghizadehghalehjoughi, Ahmet Hacimuftuoglu, and Sueda Hekimoglu. (2019). "Formulation and in vitro evaluation of topical nanoemulsion and nanoemulsion-based gels containing daidzein." *Journal of Drug Delivery Science and Technology* 52, 189-203.
- Karthikeyan, S., Jeeva, P. A., Jerobin, J., Mukherjee, A., & Chandrasekaran, N. (2012). Formulation and characterization of nanoemulsion coatings from *Azadirachta indica*. *International Journal of ChemTech Research*, 4, 566-570.
- Katyan, K., Sharma, R., & Sharma, A. (2022). Preparation and characterization of a fluocinolone acetonide nanoemulsion as a topical delivery system. *Journal of Medical Pharmaceutical and Allied Sciences*, 11(1), 4477-4483. <https://doi.org/10.55522/jmpa.s.V11I1.2118>
- Kaur, K., Kumar, R., & Mehta, S. K. (2016). Formulation of saponin stabilized nanoemulsion by ultrasonic method and its role to protect the degradation of quercetin from UV light. *Ultrasonics Sonochemistry*, 31, 29-38.
- Khani, S., Keyhanfar, F., & Amani, A. (2016). Design and evaluation of oral nanoemulsion drug delivery system of mebupidine. *Drug Delivery*, 23(6), 2035-2043. <https://doi.org/10.3109/10717544.2015.1088597>
- KhHussan, R. (2011). Nanoemulsion as a novel transdermal drug delivery system. *International Journal of Pharmaceutical Sciences and Research*, 2(8), 1938-1946.
- Klang, V., Matsko, N., Zimmermann, A.-M., Vojnikovic, E., & Valenta, C. (2010). Enhancement of stability and skin permeation by sucrose stearate and cyclodextrins in progesterone nanoemulsions. *International Journal of Pharmaceutics*, 393(1-2), 152-160. <https://doi.org/10.1016/j.ijpharm.2010.04.029>
- Klang, V., & Valenta, C. (2011). Lecithin-based nanoemulsions. *Journal of Drug Delivery Science and Technology*, 21(1), 55-76. [https://doi.org/10.1016/S1773-2247\(11\)50006-1](https://doi.org/10.1016/S1773-2247(11)50006-1)
- Kotta, S., Khan, A. W., Ansari, S. H., Sharma, R. K., & Ali, J. (2014). Anti-HIV nanoemulsion formulation: Optimization and in vitro-in vivo evaluation. *International Journal of Pharmaceutics*, 462(1-2), 129-134. <https://doi.org/10.1016/j.ijpharm.2013.12.038>
- Kumar, K., Singh, L., Mishra, S., & Singh, V. K. *Preparation and optimization of nanoemulsion*.
- Kumar, S. (2014). Role of nano-emulsion in pharmaceutical sciences-a review. *AJRPSB*, 2(1), 1-15.
- Kuo, F., Subramanian, B., Kotyla, T., Wilson, T. A., Yoganathan, S., & Nicolosi, R. J. (2008). Nanoemulsions of an anti-oxidant synergy formulation containing gamma tocopherol have enhanced bioavailability and anti-inflammatory properties. *International Journal of Pharmaceutics*, 363(1-2), 206-213. <https://doi.org/10.1016/j.ijpharm.2008.07.022>
- Lala, R. R., & Awari, N. G. (2014). Nanoemulsion-based gel formulations of COX-2 inhibitors for enhanced efficacy in inflammatory conditions. *Applied Nanoscience*, 4(2), 143-151. <https://doi.org/10.1007/s13204-012-0177-6>
- Lin, P.-Y., Chen, K.-H., Miao, Y.-B., Chen, H.-L., Lin, K.-J., et al. (2019). Phase-changeable nanoemulsions for oral delivery of a therapeutic peptide: Toward targeting the pancreas for antidiabetic treatments using lymphatic transport. *Advanced Functional Materials*, 29(13), 1809015. <https://doi.org/10.1002/adfm.201809015>
- Lu, R., Liu, S., Wang, Q., & Li, X. (2015). Nanoemulsions as novel oral carriers of stiripentol: Insights into the protective effect and absorption enhancement. *International Journal of Nanomedicine*, 10, 4937-4946. <https://doi.org/10.2147/IJN.S87471>
- Mahboobian, M. M., Seyfoddin, A., Rupenthal, I. D., Aboofazeli, R., & Foroutan, S. M. (2017). Formulation development and evaluation of the therapeutic efficacy of brinzolamide containing nanoemulsions. *Iranian Journal of Pharmaceutical Research*, 16(3), 847-857.
- Mahe, P. G., Fenelon, M. A., Zhou, Y., Kamrul Haque, M., & Roos, Y. H. (2011). Optimization of beta-casein stabilized nanoemulsions using experimental mixture design. *Journal of Food Science*, 76(8), C1108-C1117. <https://doi.org/10.1111/j.1750-3841.2011.02343.x>
- Makidon, P. E., Nigavekar, S. S., Bielinska, A. U., Mank, N., Shetty, A. M., et al. (2010). Characterization of stability and nasal delivery systems for immunization with nanoemulsion-based vaccines. *Journal of Aerosol Medicine and Pulmonary Drug Delivery*, 23(2), 77-89. <https://doi.org/10.1089/jamp.2009.0766>
- Malik, P., Ameta, R. K., & Singh, M. (2014). Preparation and characterization of bionanoemulsions for improving and modulating the antioxidant efficacy of natural phenolic antioxidant curcumin. *Chemico-Biological Interactions*, 222, 77-86. <https://doi.org/10.1016/j.cbi.2014.07.013>
- Mansour, H. M., Rhee, Y.-S., & Wu, X. (2009). Nanomedicine in pulmonary delivery. *International Journal of Nanomedicine*, 4, 299-319. <https://doi.org/10.2147/ijn.s4937>
- Mansur, R. E. (2018). Formulation characterization and in vitro drug release of hydrogel-thickened nanoemulsions for topical delivery of 8-methoxypsoralen. *Materials Science and Engineering. Part C*, 92, 245-253.
- McClements, D. J. (2012). Nanoemulsions versus microemulsions: Terminology, differences, and similarities. *Soft Matter*, 8(6), 1719-1729. <https://doi.org/10.1039/C2SM06903B>
- McClements, D. J., & Xiao, H. (2012). Potential biological fate of ingested nanoemulsions: Influence of particle characteristics. *Food and Function*, 3(3), 202-220. <https://doi.org/10.1039/C1FO10193E>
- Meng, L., Xia, X., Yang, Y., Ye, J., Dong, W., et al. (2016). Co-encapsulation of paclitaxel and baicalein in nanoemulsions to overcome multidrug resistance via oxidative stress augmentation and P-glycoprotein inhibition. *International Journal of Pharmaceutics*, 513(1-2), 8-16. <https://doi.org/10.1016/j.ijpharm.2016.09.001>
- Morais Diane, J. M., & Burgess, J. (2014). Vitamin E nanoemulsions characterization and analysis. *International Journal of Pharmaceutics*, 465(1-2), 455-463. <https://doi.org/10.1016/j.ijpharm.2014.02.034>
- Morsi, N. M., Mohamed, M. I., Refai, H., & El Sorogy, H. M. (2014). Nanoemulsion as a novel ophthalmic delivery system for acetazolamide. *International Journal of Pharmacy and Pharmaceutical Sciences*, 6(11), 227-236.
- Mou, D., Chen, H., Du, D., Mao, C., Wan, J., et al. (2008). Hydrogel-thickened nanoemulsion system for topical delivery of lipophilic drugs. *International Journal of Pharmaceutics*, 353(1-2), 270-276. <https://doi.org/10.1016/j.ijpharm.2007.11.051>
- Muheem, A., Shakeel, F., Jahangir, M. A., Anwar, M., Mallick, N., et al. (2016). A review on the strategies for oral delivery of proteins and peptides and their clinical perspectives. *Saudi Pharmaceutical Journal*, 24(4), 413-428. <https://doi.org/10.1016/j.jpsps.2014.06.004>
- Nasr, M., Nawaz, S., & Elhissi, A. (2012). Amphotericin B lipid nanoemulsion aerosols for targeting peripheral respiratory airways via nebulization. *International Journal of Pharmaceutics*, 436(1-2), 611-616. <https://doi.org/10.1016/j.ijpharm.2012.07.028>
- Nigade, P. M., Patil, S. L., & Tiwari, S. S. (2012). Self-emulsifying drug delivery system (SEDDS): A review. *International Journal of Pharmacy and Biological Sciences*, 2(2), 42-52.
- Ozturk, B., Argin, S., Ozilgen, M., & McClements, D. J. (2015). Formation and stabilization of nanoemulsion-based vitamin E delivery systems using natural biopolymers: Whey protein isolate and gum arabic. *Food Chemistry*, 188, 256-263. <https://doi.org/10.1016/j.foodchem.2015.05.005>
- Pawar, V. K., Panchal, S. B., Singh, Y., Meher, J. G., Sharma, K., Singh, P., Bora, H. K., Singh, A., Datta, D., & Chourasia, M. K. (2014). Immunotherapeutic vitamin E nanoemulsion synergies the antiproliferative activity of paclitaxel in breast cancer cells via modulating Th1 and Th2 immune response. *Journal of Controlled Release*, 196, 295-306. <https://doi.org/10.1016/j.jconrel.2014.10.010>
- Polychniatou, V., & Tzia, C. (2014). Study of formulation and stability of co-surfactant free water-in-olive oil nano- and submicron emulsions with food grade non-ionic surfactants. *Journal of the American Oil Chemists' Society*, 91(1), 79-88. <https://doi.org/10.1007/s11746-013-2356-3>
- Rapoport, N., Christensen, D. A., Kennedy, A. M., & Nam, K.-H. (2010). Cavitation properties of block copolymer stabilized phase-shift nanoemulsions used as drug carriers. *Ultrasound in Medicine and Biology*, 36(3), 419-429. <https://doi.org/10.1016/j.ultrasmedbio.2009.11.009>
- Reddy, S., & Tripura Sundari, P. (2019). *Formulation and evaluation of nanoemulsion for solubility enhancement of febuxostat*.
- Ribeiro, L. N. M., Rodrigues da Silva, G. H., Couto, V. M., Castro, S. R., Breitkreitz, M. C., et al. (2020). Functional hybrid nanoemulsions for sumatriptan intranasal delivery. *Frontiers in Chemistry*, 8, 589503. <https://doi.org/10.3389/fchem.2020.589503>

- Salimi, A., & Moghimipour, E. (2017). Preparation and evaluation of celecoxib nanoemulsion for ocular drug delivery. *Asian Journal of Pharmaceutics*, 11(3), 543-550.
- Scheller, K. J., Williams, S. J., Lawrence, A. J., Jarrott, B., & Djouma, E. (2014). An improved method to prepare an injectable microemulsion of the galanin-receptor 3 selective antagonist, SNAP 37889, using Kolliphor® HS 15. *MethodsX*, 1, 212-216. <https://doi.org/10.1016/j.mex.2014.09.003>
- Schwarz, J. C., Klang, V., Karall, S., Mahrhauser, D., Resch, G. P., & Valenta, C. (2012). Optimisation of multiple W/O/W nanoemulsions for dermal delivery of aciclovir. *International Journal of Pharmaceutics*, 435(1), 69-75. <https://doi.org/10.1016/j.ijpharm.2011.11.038>
- Shafiq, S., Shakeel, F., Talegaonkar, S., Ahmad, F. J., Khar, R. K., & Ali, M. (2007). Development and bioavailability assessment of ramipril nanoemulsion formulation. *European Journal of Pharmaceutics and Biopharmaceutics*, 66(2), 227-243. <https://doi.org/10.1016/j.ejpb.2006.10.014>
- Shaikh, N. M., Vijayendra Swamy, S. M., Narsing, N. S., & Kulkarni, K. B. (2019). Formulation and evaluation of nanoemulsion for topical application. *Journal of Drug Delivery and Therapeutics*, 9(4-s), 370-375. <https://doi.org/10.22270/jddt.v9i4-s.3301>
- Shakeel, F., Baboota, S., Ahuja, A., Ali, J., Aqil, M., & Shafiq, S. (2007). Nanoemulsions as vehicles for transdermal delivery of aceclofenac. *AAPS PharmSciTech*, 8(4), E104. <https://doi.org/10.1208/pt0804104>
- Shakeel, F., Baboota, S., Ahuja, A., Ali, J., Aqil, M., & Shafiq, S. (2008). Accelerated stability testing of celecoxib nanoemulsion containing cremophor-EL. *African Journal of Pharmacy and Pharmacology*, 2, 179-183.
- Sharif Makhmalzadeh, B., Torabi, S., & Azarpanah, A. (2012). Optimization of ibuprofen delivery through rat skin from traditional and novel nanoemulsion formulations. *Iranian Journal of Pharmaceutical Research*, 11(1), 47-58.
- Sharma, N., Mishra, S., Sharma, S., Deshpande, R. D., & Sharma, R. K. (2013). Preparation and optimization of nanoemulsions for targeting drug delivery. *International Journal of Drug Development and Research*, 5(4), 37-48.
- Shi, Y., Li, H., Li, J., Zhi, D., Zhang, X., Liu, H., Wang, H., & Li, H. (2015). Development, optimization and evaluation of emodin loaded nanoemulsion prepared by ultrasonic emulsification. *Journal of Drug Delivery Science and Technology*, 27, 46-55. <https://doi.org/10.1016/j.jddst.2015.04.003>
- Singh, K. K., & Vingkar, S. K. (2008). Formulation, antimalarial activity and biodistribution of oral lipid nanoemulsion of primaquine. *International Journal of Pharmaceutics*, 347(1-2), 136-143. <https://doi.org/10.1016/j.ijpharm.2007.06.035>
- Sinko, P. J., Allen, L. V., Jr., Popovich, N. G., & Ansel, H. C. (2006). Martin's physical pharmacy and pharmaceutical sciences.
- Srilatha, R., Aparna, C., Srinivas, P., & Sadanandam, M. (2013). Formulation, evaluation and characterization of glipizide nanoemulsions. *Asian Journal of Pharmaceutical and Clinical Research*, 6(2), 66-71.
- Sun, W., Ma, X., Wei, X., & Xu, Y. (2014). Nano composite emulsion for sustained drug release and improved bioavailability. *Pharmaceutical Research*, 31(10), 2774-2783. <https://doi.org/10.1007/s11095-014-1374-7>
- Tamarkin, D., Besonov, A., Eini, M., & Danziger, J. (2007). Foam prepared from nanoemulsions and uses. In Google Patents.
- Tamilvanan, S. (2004). Submicron emulsions as a carrier for topical (ocular and percutaneous) and nasal drug delivery. *Indian J. Pharm. Educ.*, 38(2), 73-78.
- Tan, S. L., Stanslas, J., Basri, M., Abedi Karjiban, R. A., Kirby, B. P., et al. (2015). Nanoemulsion-based parenteral drug delivery system of carbamazepine: Preparation, characterization, stability evaluation and blood-brain pharmacokinetics. *Current Drug Delivery*, 12(6), 795-804. <https://doi.org/10.2174/156720181266615090112544>
- Tarik Alhamdany, A., Saeed, A. M. H., & Alaayedi, M. (2021). Nanoemulsion and solid nanoemulsion for improving oral delivery of a breast cancer drug: Formulation, evaluation, and a comparison study. *Saudi Pharmaceutical Journal*, 29(11), 1278-1288. <https://doi.org/10.1016/j.jsps.2021.09.016>
- Trotta, M. (1999). Influence of phase transformation on indomethacin release from microemulsions. *Journal of Controlled Release*, 60(2-3), 399-405.
- Uluata, S., Decker, E. A., & McClements, D. J. (2016). Optimization of nanoemulsion fabrication using microfluidization: Role of surfactant concentration on formation and stability. *Food Biophysics*, 11(1), 52-59. <https://doi.org/10.1007/s11483-015-9416-1>
- Vyas, T. K., Amiji, M. M., & Shahiwala, A. (2008). Improved oral bioavailability and brain transport of saquinavir upon administration in novel nanoemulsion formulations. *International Journal of Pharmacy*, 347(1-2), 93-101.
- Wagh, M. R., & Dr Mane, D. (2022). Preparation and evaluation of intranasal nanoemulsion of zolmitriptan, almotriptan. *Journal of Pharmaceutical Negative Results*, 6122-6133.
- Wang, L., Li, X., Zhang, G., Dong, J., & Eastoe, J. (2007). Oil-in-water nanoemulsions for pesticide formulations. *Journal of Colloid and Interface Science*, 314(1), 230-235. <https://doi.org/10.1016/j.jcis.2007.04.079>
- Wang, X., Jiang, Y., Wang, Y.-W., Huang, M.-T., Ho, C.-T., & Huang, Q. (2008). Enhancing anti-inflammation activity of curcumin through O/W nanoemulsions. *Food Chemistry*, 108(2), 419-424. <https://doi.org/10.1016/j.foodchem.2007.10.086>
- Yilmaz, E., & Borchert, H.-H. (2005). Design of a phytosphingosine-containing, positively-charged nanoemulsion as a colloidal carrier system for dermal application of ceramides. *European Journal of Pharmaceutics and Biopharmaceutics*, 60(1), 91-98. <https://doi.org/10.1016/j.ejpb.2004.11.009>
- Yilmaz, E., & Borchert, H.-H. (2006). Effect of lipid-containing, positively charged nanoemulsions on skin hydration, elasticity and erythema- an *in vivo* study. *International Journal of Pharmaceutics*, 307(2), 232-238. <https://doi.org/10.1016/j.ijpharm.2005.10.002>
- Yukuyama, M. N., Ghisleni, D. D. M., Pinto, T. J. A., & Bou-Chacra, N. A. (2016). Nanoemulsion: Process selection and application in cosmetics-A review. *International Journal of Cosmetic Science*, 38(1), 13-24. <https://doi.org/10.1111/ics.12260>
- Zhang, R., Yang, J., Luo, Q., Shi, J., Xu, H., & Zhang, J. (2022). Preparation and *in vitro* and *in vivo* evaluation of an isoliquiritigenin-loaded ophthalmic nanoemulsion for the treatment of corneal neovascularization. *Drug Delivery*, 29(1), 2217-2233. <https://doi.org/10.1080/10717544.2022.2096714>
- Zhang, T., Dong, D., Lu, D., Wang, S., & Wu, B. (2016). Cremophor EL-based nanoemulsion enhances transcellular permeation of emodin through glucuronidation reduction in UGT1A1-overexpressing MDCKII cells. *International Journal of Pharmaceutics*, 501(1-2), 190-198. <https://doi.org/10.1016/j.ijpharm.2016.01.067>
- Zhang, Y., Shang, Z., Gao, C., Du, M., Xu, S., et al. (2014). Nanoemulsion for solubilization, stabilization, and *in vitro* Release of pterostilbene for oral delivery. *AAPS PharmSciTech*, 15(4), 1000-1008. <https://doi.org/10.1208/s12249-014-0129-4>
- Zhu, L., Li, M., Dong, J., & Jin, Y. (2015). Dimethyl silicone dry nanoemulsion inhalations: Formulation study and anti-acute lung injury effect. *International Journal of Pharmaceutics*, 491(1-2), 292-298. <https://doi.org/10.1016/j.ijpharm.2015.06.041>

Cite this article: Saini A, Chandel R, Bala A. Nano-emulsion formulations: Recent advancements and Applications Institute of Pharmaceutical Sciences, IET Bhaddal Punjab, India. *Life Sci Res Commn.* 2026;2(3):182-92.