IJPSR (2024), Volume 15, Issue 7 (Review Article)

INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES AND RESEARCH

Received on 04 December 2023; received in revised form, 06 February 2024; accepted, 16 April 2024; published 01 July 2024

NANOEMULSION: A CARRIER FOR DRUG DELIVERY

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Keywords:

Nanoemulsion, Types, Methods of preparation, Properties, Instability, Applications

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ABSTRACT: Researchers' interest in nanotechnology, and specifically nanoemulsions (NEs), has grown over time. NEs have a significant role in various sectors because of their droplet size is small and large surface area. The components, characteristics, creation, and applications are outlined in this review article. This article also discusses the benefits and drawbacks of nanoemulsion. High input energy and low input energy approaches can be utilized to create nanosized emulsions. High-pressure homogenization, microfluidization, and ultrasonic emulsification are all extensively discussed in high energy approaches. Low energy methods put an emphasis on Spontaneous Emulsification, Phase Inversion Composition (PIC), Phase Inversion Temperature (PIT), and D-phase Emulsification (DPE) techniques. The uses of NEs in the fields of medication delivery and cosmetics are discussed. The evaluation parameter and the future aspect of nanoemulsion are also discussed in this article.

INTRODUCTION: In the modern period, nanotechnology is one of the key techniques utilised by drug's manufacturers, particularly NEs, which are employed in systems of drug delivery and also employed for medications that are challenging for dissolving in water [1]. The distribution of medications, insecticides, and other biological substances presents a challenge that has been extensively studied and addressed through the use of nanoemulsion as a carrier system. The actual emulsion is made up of two or more immiscible liquids that are spread in the form of tiny droplets in phase of continuous with boundaries of interface [2].

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.15(7).1914-28

This article can be accessed online on www.ijpsr.com

DOI link: https://doi.org/10.13040/IJPSR.0975-8232.15(7).1914-28

The NEs spheres are isotropic, homogenous and systems which are thermodynamically unstable, made of two liquids which are immiscible, in which first liquid is disperse against the second with droplets of nanoscale [3]. The solid sphere with a lipophilic, amorphous, and negatively charged surface is a carrier [4]. This system of emulsion has a broad and area of steady interface, and it shield the articles from unfavourable external factors [5]. Non-synthetic surfactants are quite uncommon in nanoemulsions; the majority of them are synthetic [6].

To achieve the thermodynamic stability of non-equilibrium (NE) systems, two immiscible liquids can be combined using an emulsifying agent such as surfactants and cosurfactants, along with the application of physical or physiochemical energy. This process results in the formation of a single phase where the shape and size of the dispersed particles distinguish between emulsions (ranging

from 1 to 20 micrometers) and NEs (ranging from 10 to 200 nanometers) [7]. It's important to note that NEs and emulsions differ significantly in terms of their long-term stability. There are three techniques to prepare NEs:

Oil-in-Water (O/W) Nanoemulsion: In this process, oil is continuously dispersed within phase of an aqueous.

Water-in-Oil (W/O) Nanoemulsion: In this process, water is dispersed within a continuous phase of oil.

The Bicontinuous Phase: NEs can be viewed as bicontinuous structures or as spherical swelling micelles, which gives them a range of shapes [8].

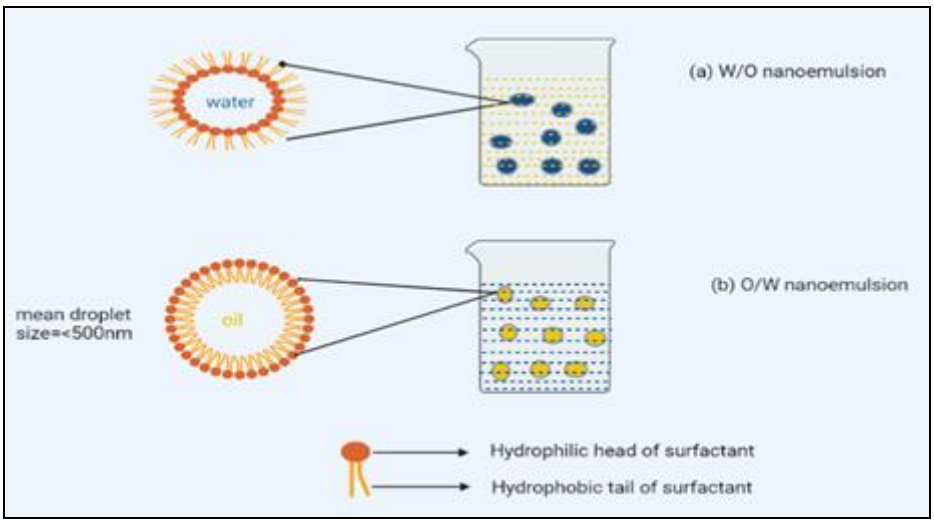

FIG. 1: (A) WATER-IN-OIL NES AND (B) OIL-IN-WATER NES

The result of the sequence during formulation in which different compounds are mixed is a crucial factor to take into account while manufacturing nanoemulsions because the preparation of NEs plays a significant role. It is crucial to note that the oily phase must first be combined with surfactants before producing nanoemulsions. As a result, conditions that are very favourable for the production of nanoemulsions become apparent. In contrast, producing "macroscopic" emulsions would be encouraged by the first mixing of surfactants and water [9]. Nanoemulsions are currently made utilising a variety of techniques, which can be broadly classified as low input energy, high-energy, or a combination of the two emulsification processes [10].

The use of mechanical instruments that produce powerful turbulent forces which phases of oil and phases of water to produce oil droplet defines high input energy techniques. This procedure makes use of sonication, microfluidizers, and high-pressure homogenizers [11]. Low input energy techniques, on another side, emulsify by exploiting the system's inherent chemical energy [12]. This is achieved by changing the intrinsic physicochemical properties of the excipient, co-surfactant, and surfactant of formulation [13].

Properties of Nanoemulsion: When compared to larger size emulsion systems, nanoemulsions exhibit a number of unique and interesting characteristics. Here are some of the most distinctive features and benefits:

The interfacial tension of oil-in-water is very low in dispersed phase, which ranges in size from 5 nm to 200 nm. Nes are transparent because their size of droplets is lower than 25% of wavelength of visible light [7].

Because their small droplet size, nanoemulsions do not exhibit the issues that are typically associated with macroemulsions, such as flocculation, coalescence, sedimentation and inherent creaming (gravitationally driven Creaming) [14].

In comparison to macro emulsions, NEs have a significantly greater free energy and surface area [15].

Nanoemulsions can be manufactured as cosmetic formulation such as liquids, sprays, cream and foam. They can also be generated in a variety of

non-toxic and non-irritating formulations, making it easy to apply them to skin and mucous membranes.

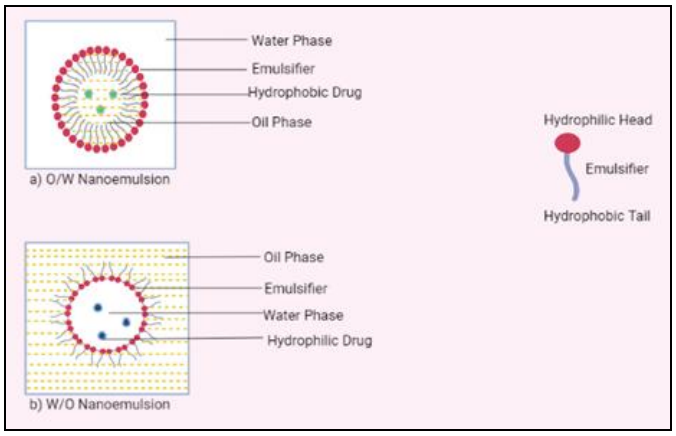

FIG. 2: STRUCTURE OF NANOEMULSION

Components of Nanoemulsion: The followings are the three important elements of nanoemulsions:

- Oil
- Surfactant/Co-surfactant
- Aqueous phase

Oils: Drug transport is increased when oils are employed to solubilize lipophilic medicines. The topical medication delivery from Oil-in-water and Water-in-oil NEsmay be modified depending on the oil component used [16]. Oils (essential), Free Fatty Acids, and other oil phases having non-polar molecular characteristics, for instance, can be employed as oil phases in nanoemulsions. The stability, formation, and properties of NEs are influenced by various physical and chemical variables, including the Viscosity, Water Solubility, Density, Polarity, Refractive Index, and Interfacial Tension of the oil phase [17].

Surfactant (Surface Active agents): Polar and nonpolar regions make up the two components of surfactant molecules. They are divided into four categories: anionic, cationic, non-ionic, and zwitter ionic surfactant, depends on the classification of polar group existing in the molecule. By reducing the tension of interfacial and making miscible liquid from two immiscible liquids, surfactants play an important role in the creation of nanoemulsions [18]. Purpose of the surfactant is to stabilise the nanoemulsion and shrink the size of its droplets. In the production of cosmetics, non-ionic surfactants are chosen due to their ability to effectively reduce interface stress and prevent skin irritation [19]. A transient emulsion is created when the oil and water phases are combined, and as a outcome of the coalescence of the scattered granules, into two phases separated from the mixture [20]. Because of the distribution of broad-chain length in mixed surfactants, stability in nanoemulsions can also be improved [21].

Co-surfactant: Co-surfactants are required because one surfactant may not be sufficient to lower the oil/water interfacial tension needed to prepare nanoemulsions. They do this by making the junction more fluid, which lowers interfacial tension [22]. The stability of the nanoemulsion and the droplet's size may be influenced because of the aqueous phase. The pH and the presence of electrolytes in the aqueous phase must be carefully assessed [23]. In the aqueous phase, water can mix with other polar molecules. The features of the aqueous phase, which rely on amounts and kinds of components, also affect the physicochemical, stability and formulation quality of the NEs. These characteristics include Phase Behaviour, Density, Rheology, pH, Ionic Strength, Polarity, Refractive Index, and Interfacial Tension [20].

Additives: Additives that extend the shelf life of nanoemulsions.

TABLE 1: EXAMPLE

Oils	Emusifiers		Additives
	Surfactant	Cosurfactant	
Captex 355	Capryol 90	Transcutol p	Tonocitymodifier (Glycerol, Sorbitol and Xylitol)
Captex 200	Gelucire 44/14	Ethyleneglycol	Sugars (Glucose, Sucrose, Fructose and Maltose)
Witepsol	Cremophor RH 40	Propylene glycol	Antioxidants (Ascorbic acid and Tocopherol)
Myritol 318	Imwitor 191, 308, 742, 780,	Ethanol	
Isopropyl Myristate	Tween 80	Propanol	
IPM	PEG MW>4000	Polaxamer	
Castor oil	Plurol Oleique CC 467	PEG400	
Corn oil	Poloxamer 124 and 188	PEG300	

Coconut oil	Softigen 701, 767	Glycerine
Linseed oil	Polysorbate80,20	
Mineral oil	Polyoxy-60	
Olive oil	Caprylic glyceride	
Peanut oil	Sorbitone monooleate	

During formation of Nanoemulsion following Factors are considered:

1. The molecules of dispersed phase must be insoluble in the continuous phase
2. A flexible interface must be formed
3. In continuous phase the surfactant should be soluble
4. All components must be added in a controlled manner [23].

TABLE 2: DIFFERENCE BETWEEN EMULSION AND NANOEMULSION

S. no.	Emulsion	Nanoeulsion
1	Anisotropic in nature	Isotropic in nature
2	Appearance of emulsion is cloudy	Appearance of nanoemulsion is transparent
3	Emulsion is thermodynamically unstable	Nanoemulsion is thermodynamically stable as compare to emulsion
4	Methods used for preparation are wet gum method, dry gum method	Methods used for preparation are microfluidization, ultrasound generators etc.
5	Surfactant used in higher concentration (20-25%)	Surfactant used in lower concentration (5-10%)
6	Stability problems like creaming, sedimentation and phase inversion etc may occur	Stability problems like creaming, sedimentation and phase inversion are not occur
7	Kinetic stability is excellent	Kinetically unstable

TABLE 3: DIFFERENCE BETWEEN NANOEMULSION AND MICROEMULSION

S. no.	Nanoemulsion	Microemulsion
1	Nanoemulsion are thermodynamic-ally unstable as compared to microemulsion	Microemulsion are thermodynamically stable
2	Components of nanoemulsions are Water, Oil, Surfactant and Co-surfactant. As surface active agents, protein and polysaccharides can also be used	Components are oil, water, surfactant and possibly a co-surfactant
3	Low surfactant/oil ratio are used	Large surfactant/oil ratio are used
4	Appearance of nanoemulsion is transparant to opaque	Appearance of microemulsion is transparant
5	The droplet form is generally spherical due to high interfacial tension relatively	Droplet form depends on the oil content and the optimum curvature of the surfactant monolayer
6	Input of some external energy is required to convert the separate components into a collidal dispersion, like ultrasound for the production of nanoemulsion	Light magnetic agitation is required for the formation of microemulsion
7	Nanoemulsion are kinetically unstable	Microemulsion possess some kinetic stability

TABLE 4: COMPARISON OF EMULSION, NANOEMULSION AND MICROEMULSION

Parameter	Emulsion	Nanoemulsion	Microemulsion
Type of dispersion	Coarse	Colloidal	Colloidal
Internal phase size(µl)	Above 0.5	Up to 0.25	Up to 0.15
Thermodynamic stability	Unstable	Unstable	Stable
Formation/Preparation	Require energy (high)	Require energy (low/high)	Spontaneous (low)
Surfactant amount	Surfactant and co-surfactant combination is required in greater amount	Surfactant amount is required in less amount	Surfactant amount is required in less amount
Consistency/Texture	Fluid/semi-solid	Fluid	Fluid
Turbidity/Physical appearance	Milky/Creamy	May vary/Transparent	Transparent
Surfactant to oil ratio	Low	Moderate	High
Effect of temperature and Ph	Stable to pH changes and temperature changes	Stable to pH changes and temperature changes	Effected by changes in composition, change in temperature and change

Phases	Biphasic	Biphasic	in pH Mono-phasic

Advantages of Nanoemulsion: The interest towards NEs for the purpose to uses for health care treatment and also cosmetics as well as in personal care is because of the following reasons and benefits [24, 25]:

1. Gravity force is greatly reduced by the extremely small droplet size, andmotion i.e. brownian alone might be enough to defy gravity. This indicates that during storage there will be no creaming or sedimentation.
2. Smaller droplet size of the NEs prevents the flocculating of the droplets. It is possible for the system to stay scattered without separation because weak flocculation is revented.
3. The little droplets size also stop them from coalescing and because of their elastic property they also stop surface fluctuations.
4. The effective transport of active substances via the skin is possible with nano-emulsions. The emulsion system's wide surface area enables quick active penetration.
5. They may have a pleasing aesthetic aspect and skin feel due to the absence of thickeners, their fluidity (at moderate concentration of oil), and clear nature of the system.
6. Nanoemulsions can be made with a small surfactant concentration, in contrast to microemulsions, which need a high surfactant concentration, often around 20% and greater. A surfactant concentration in the range of 5% to 10% may be adequate for a 20% o/w nano-emulsion. Surfactants that are approved for human consumption (GRAS) are typically used to create nano-emulsions, which can be ingested orally.
7. The droplets' modest size makes it possible for them to deposit consistently on substrates. The entire system’s low surface tension and the low oil-in-water droplet’s low interfacial tension may also improve wetting, spreading, and penetration.
8. Fragrances, can be used in products of personal care, can be delivered *via* nano-emulsions. This could also be used in perfumes, which should be made without alcohol.
9. Nanoemulsions can replace less stable liposomes and vesicles, and under certain conditions, phases of lamellar liquid crystalline can form arounds the droplets of NEs.
10. Smaller NE droplets have more surface area, which improves absorption [26].
11. NE production requires less energy [26].
12. Helps to dissolve lipophilic medications and mask their unpleasant flavour [27, 28].
13. Not recognized as harmful and not known to irritate [29].
14. Because NEs can protect chemically unstable substances from oxidative and light destruction, they are more stable [30].
15. Different NE formulations can be created (e.g., liquids, spray and creams) [28].
16. Vesicles and liposomes may be substituted [31].
17. Increases a drug's bioavailability [32].

Disadvantages of Nanoemulsion [24, 25]:

1. The development of nano-emulsions frequently requires the use of specialised techniques of application such as the use of homogenizers (high-pressure) and ultrasonics. Recently instruments (like the Microfluidiser) become accessible.
2. In industry of personal care and cosmetics, it is believed that the producing NEs is cpstly. High concentrations of emulsifiers must be utilised, along with expensive equipment.
3. Lack of knowledge on the mechanism involving the formation of droplets of submicron and function of co-surfactants.

4. The benefits of using nano-emulsions over traditional macroemulsion systems are not well-supported by the available research.

5. A deficiency of knowledge of chemistry of the interfacial necessary for the creation of nano-emulsions.

6. NEs require the support of surfactant and cosurfactant at higher concentration to stabilise the nanodroplets.

7. High-melting-point compounds can only be solubilized to a limited extent.

8. The stability of NEs may be affected by environmental factors like temperature and pH.

9. Surfactants utilised in pharmaceutical applications must be non-toxic.

Method of Preparation of Nanoemulsion: Nanoemulsion preparations are made by the utilization of both low input energy and high input energy emulsification processes. Among the high input energy methods, membrane emulsification, high homogenization, including micro fluidics abd ultrasonic emulsification are highlighted. Three low-energy emulsification methods are the EIP, PIT and afterwards spontaneous emulsification. By combining a low high energy and high input energy emulsification approach, reverse nanoemulsions can created in very glutinous conditions [33].

Methods of High Energy: It includes methods which are following:

High-Pressure Homogenization: This procedure involves applying high pressure to a system that includes an phase of aqueous, a surfactants or cosurfactants and an oil phase. The pressure is applied by the help of the homogenizer.

Poorcomponent breakdown and productivity that produces a lot of heat are some issues associated to homogenizers. This technique is typically used to create liquid O/W nanoemulsions; cream nanoemulsions with mean droplet diameters smaller than 200 nm and high viscosity or hardness cannot be created [34].

Micro Fluidization: In micro fluidization technology, a tool called a "Micro Fluidizer" is employed. A high-pressure positive displacement pump (500-200 PSI) is used to drive the product into the interaction chamber, which is made up of microscopic passages called micro channels. Submicron-sized particles are produced as the substance passes through the microchannels and enters the impingement zone.

The two solutions (the phase of aqueous and the phase of oil) were combined and in an inline homogenizer it processed to create a emulsion's cooarse. In order to develop a more stable nano emulsion, rough emulsion is processed further more in a micro fluidizer [35].

Ultra-sonication: The macroemulsion breaks down into a nanoemulsion due to the cavitation forces created by ultrasonic waves during ultrasonic emulsifications. Ultrasonicators are used in this process, which employs an ultrasonic wave-emitting search. By regulating the timing and ultrasonic energy input, required particle size and stability of the nanoemulsion will be achieved [36].

For the purpose of generating physical shear, the method of acoustic cavitation is used in ultrasonic emulsification. The phenomenon known as cavitation, which is triggered by the sound wave's pressure changes, causes microbubbles to rise and fall. Because of the intense turbulence caused by the collapse of the microbubbles, nano-sized droplets are created.

An oil and water system exposed to ultrasound radiation produces nano-sized emulsion droplets because cavitation forces are created and additional energy is provided for completely new interface shapes. Ultrasonication is widely used to produce nanoemulsions when surfactants are not present [37].

According to recent studies, the strength, time frame, and kind of surfactant used during ultrasonic emulsification all affect how well the process works.

Ultrasonication has been widely used to create nanoemulsions of food and pharmaceutical ingredients. Compared to high-energy procedures, food-grade ultrasonication produces nanoemulsions that are more stable, use less energy, and have smaller droplet sizes [38].

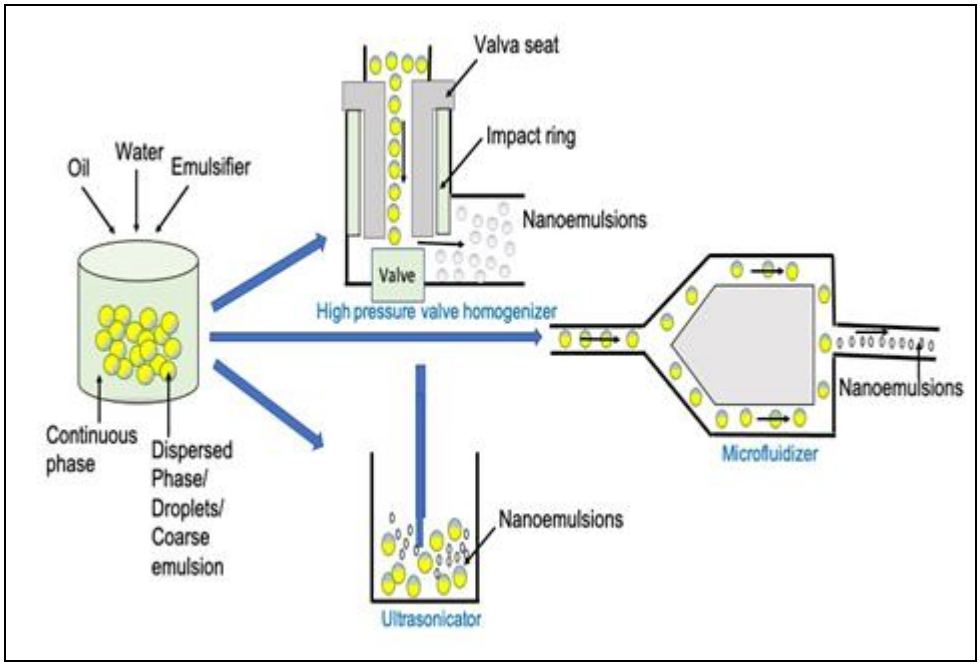

FIG. 3: HIGH ENERGY METHOD OF NANOEMULSION PREPARATION

Low Energy Methods: It involves following method:

Phase Inversion Emulsification: The Spontaneous curvature of surfactant causes phase change in this method during the emulsification process. The surfactant's spontaneous curvature can be changed with changes incompositions, temperature and other variables. Two categories of phase inversion emulsification techniques exist:

Transitional Phase Inversion Methods, which includes PIT and PIC.

Catastrophic Phase Inversion Methods, which includes EIP.

CPI, on the other hand, happens when dispersed particles are continuously added, resulting in the drops of dispersed particles combining with one another to form bicontinuous/lamellar structural phases. Transitional phase inversion occurs by variations in the surfactant's affinity or spontaneous curvature in outcome to changes in external factors like the composition and the temperature [39]. Transitional phase inversion causes changes to spontaneous curvature or surfactant affinity, whereas catastrophic phase inversion results in no changes to any of these variables [40].

Phase Inversion Temperature: This involves the temperature's change to counteract the surfactant's natural curvature. Non-ionic surfactants like polyethoxylated surfactants undergo dehydration of POE groups, this increases the substance's lipophilicity and changes its curvature. This leads to phase inversion, which produces nanoemulsion. By heating non-ionic surfactant, oil and water, method of this produces O/W emulsions. The surfactant's POE groups then gradually dehydrate as the temperature rises, becoming more lipophilic and displaying a higher affinity for the oily phase [41].

Through bi-continuous structures or intermediary liquid crystalline (such as lamellar phase), the initial oil-in-water emulsion is converted into succeeding water-in-oil nanoemulsion. At HLB temperature, a moderate temperature, the surfactant of non-ionic group exhibits a same affinity to the phase of aqueous and phase of oil and has zero curvature. Quick cooling or heating of HLB is required for efficient phase inversion in order to create emulsion of Oil-in-water or Water-in-oilnature, accordingly. Cooling or heating in rapid manner is required to create a nanoemulsion that is kinetically stable [41].

Phase Inversion Composition: The PIC approach, like the Phase Inversion Temperature approach, PI is accomplished through altering the composition of system rather than its temperature. In Phase Inversion Composition, as water is added to

mixture as one component, followed by the adding of oil or oil-surfactants to the mixture of water-surfactants. The PIC method primarily produces nanoemulsions using surfactants of non-ionic group of type of POE, while other types of surfactants maybe employed. When if water is progressively adding to phase of oil and as water fraction increases, surfactant POE chain hydrates [42]. In the PIT method, the surfactant's hydrophillic and lipophillic characteristics in the phase of water are balanced, leading to a near-zero spontaneous curvature. This outcome generates a bicontinuous or lamellar configuration. With the addition of more water, the surfactant layer structures that previously had zero curvature begin to surpass the transition composition. This changes in curvature results in inversion of phase and the formation of nanodroplets. So, a change in the system's nature causes phase inversion. pH and the addition of salt are two instances of related compositional influences [42].

Emulsion Inversion Points: CPI processes are used in the EIP technique to phase inversion. This Inversion (CPI) is created by adjusting the capacity of the dispersed particle's fraction other than surfactant properties. Once water phase has been adding to the mixture of oil-surfactants, the system begins to behave like a W/O nanoemulsion. A PIT is achieved, which results the production of bicontinuous or lamellar structures, as water droplets merge together as additional water is adding over a particular content of water while being churned constantly. By diluting more water through a bi-continuous microemulsion in between, a W/O system can transition to an O/W system, inverting its phase [43].

The process parameters, such as the rate of stirring and, consequently, rate of water intake, affect the sizes of resulting droplets of nanoemulsion. Rapid phase inversion comes from a fast rate of coalescence because catastrophic phase inversion needs the surfactant to be significantly available in the dispersed particles in order to occur. Catastrophic phase inversion, which results in the aberrant emulsion being transformed into a more stable normal emulsion [43].

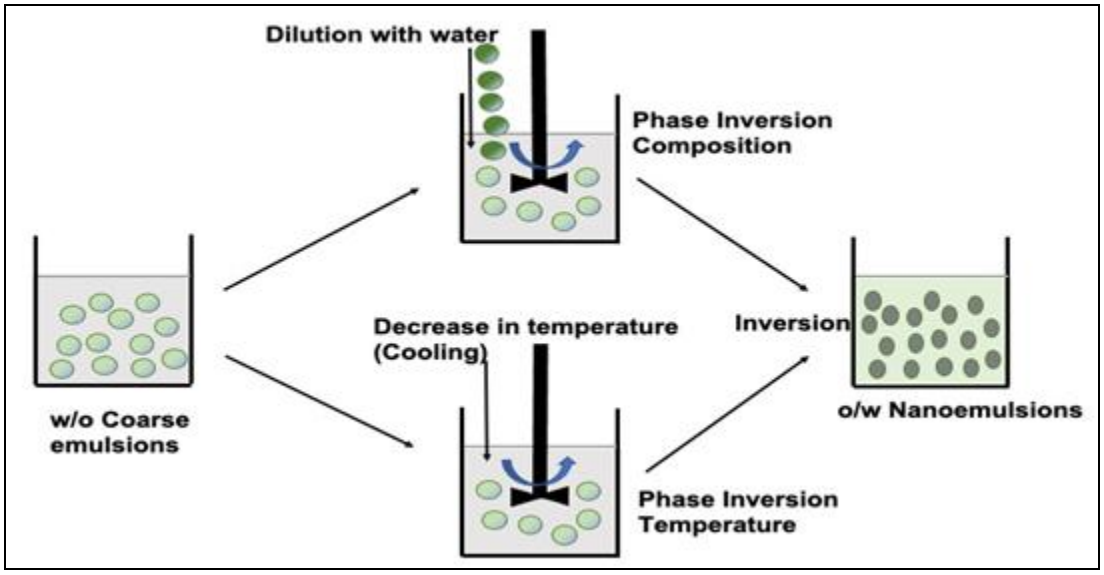

FIG. 4: LOW ENERGY METHOD OF NANOEMULSION PREPARATION

Application of Nanoemulsion in Cosmetics: Nanoemulsions are employed in cosmetics because macroemulsions exhibit the creaming, sedimentation, and flocculation that are inherent to them. NEs are highly ideal for transport of lipophillic drugs as compare to liposomes because of their lipophilic interior, and they assist the skin penetration of active components, increasing their concentration in the skin. The great surface area of the tiny droplets in nanoemulsions allows for efficient transport chemicals of active nature to the skin, which is another benefit. Using high input energy machinery during manufacture will prevent the introduction of potentially irritating surfactants. Additionally, PEG-free nanoemulsions with good stability for cometics have been produced [44]. Numerous studies suggest the use of Submicron emulsions for improved cutaneous absorption of

active substances and decreased transepidermal water loss, which supports the skin's barrier function [45]. The intrinsic lack of creaming, sedimentation, flocculation, or coalescence that macroemulsions exhibit makes nanoemulsions practical for use in cosmetics [44]. Qualities like reducing transepidermal water loss, increasing skin production, and increasing active ingredient penetrationimply that it would be beneficial for moisturizing, anti-aging, and sun care products fields where nanotechnologies are already incorporated into a variety of goods that are now on the market. It is also mentioned that it contributes to the skin-like feel of skin care formulations.

The following are some benefits of Nanoemulsions over Conventional Dosage forms [46]:

1. Absorption rate increases.
2. Variability in absorption is eliminated.
3. Helps in solubilizing drug which is lipophilic in nature.
4. For water insoluble drugs provide aqueous dosage form.
5. Helps in increasing bioavailability.
6. For delivery of products various routes likes Topical, Oral and Intravenous can be used.
7. Fastly and efficiently penetration of drugs moiety is rapid and efficient.
8. Good for hiding tastes.
9. As a medication in oil phase in O/W, provides protection from chemical reaction like hydrolysis and oxidation, water and air are not allowed to attack a nanoemulsion.
10. The patient compliance rate is higher with liquid dosage forms.
11. Less amount of energy is needed.
12. Because there are no colloidal particles or thickening agents in nanoemulsion, it has a transparent and fluid quality that enhances patient compliance and makes it safe to administer.
13. Thermodynamically NEs are stable systems, and this stability enables system to self-emulsify.
14. Compared to microemulsion, NEs formulation only needed a little quantity of surfactants. For instance, 5–10% surfactant is adequate to prepare nanoemulsions but 20–25% surfactant is needed to prepare microemulsions.

Application of Nanoemulsion in Drug Delivery:

Parenteral Delivery: Because naoemulsion can dissolve hydrophobic medications and shield them from enzymatic activity, they are consider one of the best and most efficient ways to deliver medication to blood and tissues. Nanoemulsions offer regulated and prolonged medication release for the body since they outperform emulsions [47] in a number of ways, such as the possibility of enormous surface area and energy and capacity of their to prevent problems like Flocculation, Sedimentation, and Creaming. This is because they have the ability to dissolve hydrophobic medicines and because those medications are resistant to enzymatic activity.

Clinical and preclinical tests have also been conducted on parenteral nanoemulsions. Thalidomide, which has been researched as a therapeutically useful medicine even at a dose of 25mg, is a very good example in this regard. Pharmacokinetic investigations for parenteral NEs of chlorambucil, a lipophilic anticancer medication when combined with a higher intensity ultra-sonication approach, have been carried out in a similar fashion for breast and ovarian cancer [48].

Oral Delivery: An extremely simple non-invasive method for administering drugs to patients, but this method is restricted in cases where the patient is unwilling to cooperate, such as in elderly, pediatric, and epileptic patients. In addition, some oral drugs have poor aqueous solubility, which can sometimes lead to issues with drug stability in the gastrointestinal tract. Similar enzymatic processes can occur with peptide medications, and hygroscopic medications can permeate in intestinal membranes, which again restricts intestinal absorption of such drugs. Such issues can be resolved by making the medication's particles smaller, which will boost their bioavailability,

protected them from the GIT, which increaeses their time of transit, and route the drugs to particular pathways process. Utilizing oils in nanoemulsion processes to load the medicine and subsequently improve GIT absorption is a unique strategy [49].

To improve bioavailability and target medication delivery, nanoemulsions are used in oral drug delivery systems. This approach has the potential to boost drug absorption in the gastrointestinal tract (GIT). The utility of pharmaceuticals in NEs formulation is thought to has better therapeutic potentials and is recognized as an effective method of delivering drugs to the target site [49].

Ocular Delivery: Pharmaceutical sciences have made an effort to increase the drug's contact times at the ocular surface in order to successfully permeate the cornea [50]. Researchers regularly work to develop prolonged medication release at deep tissue layers through the production of nanoemulsions by an effort to improve therapeutic effectiveness in comparison to standard medical practises.

The increased penetration of corneal and time of contact, controlled, targeted, and sustained drug delivering to region of occular, increased efficacy of therapeutics, and bypassing lacrimal glands' protective barriers and their drainage system are major benefits of this novel drug delivery system for medicine. A prime example from this stream is the nanoemulsion of dorzolamidehydrochloride, which has demonstrated rapid drug onset, sustained therapeutic action, and thermodynamic stability [51].

Intranasal Delivery: In comparison to oral and parenteral methods, which may cause paediatric children to feel more anxious, it is especially helpful for paediatric children. This conclusion is drawn from research on the direct delivery of drugs from the nose to the brain using nanoparticles. Additionally, they emphasise the necessity of testing the toxicity of nanoparticles' nasal delivery system [52].

For nasal delivery to the brain, risperidone nano-emulsions may have been made. It seems that administering this emulsion orally as opposed to intravenously will result in greater outcomes. Additionally, these emulsions may be used as a non-toxic mucosal adjuvant for the influenza vaccine virus [52].

Topical Delivery: Transdermal is a very effective drug delivery method that is currently preferred over parenteral and oral routes because it allows for controlled drug delivery [55], allows for self-administration of drugs at any time, and has a pleasant skin feel that prevents bowel ulcers and gastric irritation [53-26].

Even nanoemulsions, that can augmented through intophoresis, sonophoresis, or heat stimulus to the skin, are more effective than gels and emulsions in *in-vivo* and *in-vitro* transdermal experiments [57].

The greatest amount of medicine is absorbed when it enters the skin directly from the skin layer, through the sweat duct, or through the hair follicles. For instance, carvedilol's antioxidant properties are utilised to treat heart failure conditions. Although medicines are effectively absorb by the Gastrointestinal Tracts, when it goes through hepatic processing, its bioavailability is decreased by 23%. Additionally, this transdermal approach is effective for a number of clinical conditions, including Parkinson's disease, anxiety, and Alzheimer's disease [53, 54].

Instability in Nanoemulsion:

Physical Instability:

Creaming: A process known as "creaming" may involve the separation of scattered droplets by gravity to create a thicker, cream-like emulsion. If the oil and water phases have different densities, creaming will invariably happen in any diluted emulsion with relatively big droplets (1 µm). In an oil-in-water emulsion, the majority of oils have a lower density than water, causing them to float to the surface and form a top cream layer. Conversely, in w/o emulsions, water droplets settle at the bottom and form a lower layer.

Creaming in emulsions can often be reversed by gentle agitation, but this approach is generally considered undesirable because the emulsion's appearance is unappealing, and the patient may not receive a proper dose if the emulsion is not adequately agitated before administration. The most effective method to reduce creaming is to create emulsions with small droplet sizes and thicken the outer phase by incorporating viscosity

modifiers. Modifying density to reduce the density gap between the two phases has received minimal consideration [58].

Flocculation: Flocculation refers to a fragile and reversible bond between emulsion droplets that are separated by a confined continuous phase. While each droplet retains its distinct identity within a floccule (a cluster of droplets), the entire floccule operates as a single cohesive unit. Occasionally, floccules will redisperse with light motion. Thus, the risk of flocculation can be reduced by employing the appropriate emulsifier. Although the adsorbed emulsifier can often significantly delay the onset of coalescence after flocculation, flocculation is generally considered undesirable because floccules tend to cream more rapidly due to gravity than individual emulsion droplets [58].

Coalescence: The irreversible process by which small droplets of dispersed material combine to produce larger droplets is known as coalescence. The procedure will be continued until the emulsion splits (cracks), or until the emulsion completely separates into its oil and water phases. As the emulsion droplets approach and breach the repulsive energy barrier to reach the first minimum, they coalesce. The emulsion's stability against coalescence primarily depends on the interfacial film's capacity to withstand rupture once the droplets are in close proximity to each other at the minimum..As the oil droplets travel towards one another and begin to hamper one another, the continuous phase liquid films between them begin to drain, and the coalescence process results in the disintegration of the film. Preventions of droplet coalescence may be achieve through utilizing thick, multi-layered films composed of various polymers or rigid, densely packed elastic films created from specific emulsifier blends. These films are highly resistant to rupture, ensuring the stability of the emulsion [58].

Ostwald Ripening: Large droplets form at the utility of small ones as a result of irreversible process of Ostwald ripening. Sub-micrometer droplets (less than 600 nm) in emulsions can undergo Ostwald ripening if the dispersed particles have a significant solubility in the continuous phase. The Kelvin effect plays a direct role in Ostwald ripening, as it explains why the solubility of a partially miscible droplet increases substantially as its radius decreases. Smaller emulsion droplets are therefore more soluble than larger ones. This phenomenon result in an increasing in average size of droplets as smaller droplets are dissolved, their molecule diffuses through continuous phase, and re-deposit onto larger droplets, causing them to enlarge. Unlike coalescence, Ostwald ripening does not require any contact between droplets [58].

The characteristics of surfactant interfacial films can prevent flocculation and coalescence, but the presence of micelles can facilitate Ostwald ripening through enhancing solubilization of oil. However, addition of a smaller quantity of an immiscible second oil to the partially miscible main oil can reduce its molecular mobility, thereby preventing Ostwald ripening [58].

Emulsion Inversion: Emulsion inversion can occur occasionally in emulsions under specific conditions. The low-energy production of nanoemulsions relies on phase inversion, a phenomenon where an oil-in-water emulsions transforms into a water-in-oil emulsions at a specific temperature. This is due to the change in solubility of the emulsifier, such as some non-ionic surfactants, from being water-soluble at low temperatures to oil-soluble at high temperatures. Additionally, the inversion of an emulsion can occur due to specific interactions between different substances. For example, if a sodium salt is utilized to stabilize an oil-in-water emulsion, addition of divalent ions, like Ca2+ ions, may cause the emulsion to invert to a water-in-oil emulsion by generating calcium salt that stabilizes a water-in-oil emulsion [58].

Chemical Instability: Under emulsification conditions, all emulsion components should be chemically inert. Pharmaceutical oils must be chosen with special care because they can become rancid and develop an unpleasant odor and taste as a result of microbial contamination or oxidation by atmospheric oxygen. In order reduce these effects, antioxidants and preservatives could be added to the emulsion. Emulsification power and consistency may be lost when polymeric emulsifiers depolymerize through hydrolysis or microbial degradation. Interactions between other

components and emulsifying agent are particularly problematic as they could also result in the loss of emulsifying characteristics, which would cause the emulsion to separate. For instance, non-ionic POE emulsifiers create hydrogen bonds with phenolic preservatives, which results in poor preservation and decreased emulsifying action. Ionic emulsifying agents usually are not compatible with compounds that have the opposite charge [58].

Evaluation Parameters of Nanoemulsion [59]:

Analysis of size of Droplets: Using a Light-scattering, Particle Size Analyzer Counter, the LS 230, size of droplet analysis of nanoemulsion is measured by diffusion. Transmission electron microscopy can also be utilise to analyse the size of the droplets in a nanoemulsion (TEM).

Viscosity Determination: At various temperatures and shear rates, a Brookfield-Type Rotayional Viscometer is used to measure viscosity of nanoemulsion.

Dilution Test: This particular type can be determined by diluting a nanoemulsion with water or oil. The test is relay on observation that a NEs can have more continuous phase added to it without losing its stability. As a result, a water-in-oilNEs can be diluted with oil while an oil-in-water NEs can be diluted with water.

Drug Contents: Pre-weighed NEs are extracted by dissolving in an appropriately solvent system, and the extracts are examined using an analytical instruments like Spectrophotometer or HPLC in comparison to a standard drug solution. Abbes refractometer is used to measure the nanoemulsion's refractive index.

pH: A pH metre can be utilise to determine the pH of nanoemulsion.

Zeta Potential: Zeta PALS is a device used to test zeta potential. In nanoemulsions, it is utilise to measured the charges on the droplet's surface [60].

TABLE 5: MARKETED PREPARATION OF NANOEMULSION [61]

Drugs	Name of Brand	Indication
Propofol	Diprivan	Anesthetic
Dexamethasone	Limethason	Steroid
Flurbiprofen axetil	Ropion	Nonsteroidal analgesic
Vitamin A, D, E & K	Vitalipid	Parentral nutrition
Palmitate alprostadil	Liple	Vasodilator, platelet inhibitors

Future Perspectives of Nanoemulsion: Due to the potential of NEs for the creation of cosmetics for the skins and hairs, they can expected to be favoured as an efficient innovative system of drug delivery method for a varieties of pharmaceutical applications in the future. Being flexible, innovative drug delivery systems can also serve as bioactive delivery services *via* a variety of ways. Several of unique qualities which are properly accepted in the currentera are regulated medication delivery, targeted drug delivery, and parenteral delivery of nanoemulsions to meet nutritional needs. Because of the size of the small droplet that makes them effective mechanism of oral drug delivery, absorption from the gastrointestinal tract is greatly increased. The pharmacological's preparation appear to more stable than solution form's formulation when used as an eye drug delivery system. Undoubtedly, the pharmaceutical and industrial sectors must advance their technology in order to produce nanoemulsions, but this may only be noticeable temporarily. Only a few simple steps are required to create diverse nanoemulsions, which will more than make up for the time-consuming and tedious procedures used to create different products. They may be an effective drug of delivery strategy for phyto-pharmaceuticals, that may provide financial resources for the pharmaceutical industry, in addition to the drug delivery system such as Transdermal, Parental, Ocular, Intranasal, Pulmonary, and Vaccine.

The production cost will undoubtedly decrease if many sectors use nanoemulsion technology. Significant studies in the area of Surfactant, Co-surfactants and Emulsifiers system will also lead to the efficient usage of surfactants. NEs are so far widely used in the Medicines, Cosmetics, and several other areas to produce a large range of adaptable items. Agricultural, engineering, chemical, and physical sciences have a large range

of applications that have potential for produce positive outcomes.

CONCLUSION: It is impossible to overstate the significance of designing and creating emulsion nanocarrier systems with the goal of regulating and/or increasing the necessary bioavailability levels of medicinal medicines. Some highly intriguing physical characteristics, like optical transparency and unique elastic behaviour, result from droplet sizes being reduced to the nanoscale. Nanoemulsions, which are useful dispersions of deformable nanoscale droplets, have the potential to have a variety of flow characteristics as well as optical qualities ranging from virtually transparent to opaque in the field of nanomaterials. Furthermore, it is quite likely that nanoemulsions will play a more substantial commercial role as they can often be created with substantially low surfactanst that is needed for nanostructured lyotropic phases of microemulsio. Recent developments in this field are highlighted in the article. The several nanoemulsion carrier formulations that have been created so far have been named. Being a drug carriers for enhancing the pharmaceutical active ingredient's delivery, nanoemulsions are gaining popularity because they provide a number of benefits for the delivery of pharmaceuticals. They are adaptable to practically all distribution methods and consequently show potential in a variety of industries, including biotechnology, cosmetics, and medicines.

ACKNOWLEDGEMENT: Authors acknowledge expressing our sincere gratitude to the management of the Buddha Institute of Pharmacy for continuous support, motivation, enthusiasm, and immense knowledge.

CONFLICTS OF INTEREST: The authors declare that they have no conflict of interest.

REFERENCES:

1. Parihar A, Prajapati BG, Macwan M and Pal S: 'A Comprehensive review on applications, prepation & characterization of nanoemulsion' IP International J of Comprehensive and Adv Pharma 2023; 8(2): 104-111.
2. AN, Kovooru L, Behera AK, Kumar KPP and Srivastava P: 'A Critical review of synthesis procedures, applications and future potentialof nanoemulsion' Advances in Colloid and Interface Sciences 2021; 287.
3. Patel RB, Thakore SD and Patel MR: 'Recent survey on patents of nanoemulsions' Current Drug Delivery 2016; 13(6): 857-81.
4. Sharma N, Mishra S, Sharma S, Deshpande RD and Sharma RK: 'Preparation and optimization of nanoemulsions for targeting drug delivery' International J of Drug Development and Research 2013; 5(4): -48.
5. Kumar M, Bishnoi RS, Shukla AK and Jain CP: 'Techniques for formulation of nanoemulsion drug delivery system: a Review' Preventive Nutrition and Food Science 2019; 24(3): 225-34.
6. Shukla P and Singh S: 'A Complete review on Nanoemulsion' Indo American Journal of Pharmaceutical Sciences 2022; 9(1): 266-272.
7. Devarajan V and Ravichandran V: 'Nanoemulsions: As Modified Drug Delivery Tool' Pharmacie Globale International Journnal Comprehensive Pharmacy 2011; 2(4).
8. McClements DJ and Rao J: 'Food-Grade Nanoemulsions: Formulation, Fabrication, Properties, Performance, Biological fate, and Potential toxicity' Critical Review in Food Science and Nutrition 2011; 51(4): 285-330.
9. Anton N and Vandamme TF: 'Nano-emulsions and micro-emulsion: Clarification of the critical differences' Pharmaceutical Research 2011; 28(5): 978-985.
10. Nagan CL, Basri M, Lye FF, Masoumi HRF, Tripathy M, Karjiban RA and Abdulmalek E: 'Comparision of Box-Behnken and Central Composite Designs in Optimization of Fullerence Loaded Palm-based Nano-emulsions for Cosmeceutical Application' Industrial Crops and Products 2014; 59: 309-317.
11. Al-Sabagh AM, Emara MM, Noor El-Din MR and Aly WR: Formation of water-in-diesel oil nano-emulsions using high energy method and studying some of their surface active properties' Egyptian Journal of Petroleum 2011; 20: 17-23.
12. Saberi AH, Fang Y and McClements DJ: 'Fabrication of Vitamin E-enriched Nanoemulsion: Factors Affecting Particle Size Using Spontaneous Emulsification' Journal of Colloid and Interface Science 2013; 391: 95-102.
13. Anton N, Benoit JP and Saulnier P: 'Design and Production of Nanopaticles Formulated from Nano-emulsion Templates – A Review. Journal of Control Release 2008; 128(3): 185-199.
14. Sharma S and Sarangdevot K: 'Nanoemulsion for Cosmetics' International Journal of Advanced Research in Pharmaceutical and Biosciences 2012; 2(3): 408-415.
15. Shah P, Bhalodia D and Shelat P: 'Nanoemulsion: A Pharmaceutical Review' Systematic Reviews in Pharmacy 2010; 1(1): 24-32.
16. Zhang LW, AL-Suwayeh SA, Hung CF, Chen CC and Fang JY: 'Oil Components Modulate the Skin Delivery of 5-aminolevulinic acid and its Ester Prodrug from Oil-in-Water and Water-in-Oil Nanoemulsion' International Journal of Nanomedicine 2011; 6: 693-704.
17. Azrini AN, Elgharbawy AAM, Motlagh SR, Samsudin N and Salleh HM: 'Nanoemulsion: Factory for Food, Pharmaceutical and Cosmetics' Green Sustainable Chemical Processes 2019; 7(9): 617:1-34.
18. Peng LC, Liub CH, Kwan CC and Huang KF: 'Optimization of water-in-oil nanoemulsions by mixed surfactants' Colloids and Surfaces A Physicochemcal Engineering Aspects 2010; 370(1): 136-142.
19. Faria-Silva C, Costa AM, Ascenso A, Ribeiro HM, Marto J, Goncalves L, Carvalherio M and Simoes S: 'Nanoemulsion for Cosmetic Products' Nanocosmetics 2020; 1: 59-77.
20. Azrini N, Azmi N, Elgharbawy AAM, Motlagh SR, Samsudin N and Salleh HM: 'Nanoemulsion: Factory for

Food, Pharmaceutical and Cosmetics' Green Sustainable Chemical Processes 2019; 7(9): 617:1-34.
21. Lu WC, Huang DW, Wang CR, Yeh CH, Tsai JC, Haung YT and Li PH: 'Preparation, Characterization, and Antimicrobial Activity of Nanoemulsions Incorporating Citral Essential Oil' Journal of Food and Drug Analysis 2018; 26(1): 82-89.
22. Preeti, Sambhakar S, Malik R, Bhatia S, Harrasi AAI, Rani C, Saharan R, Kumar S, Geeta and Sehrawat R: 'Nanoemulsion: An Emerging Novel Technology for Improving the Bioavailability of Drugs' Scentifica 2023.
23. Anton N and Vandamme TF: 'The Universality of low-energy Nano-emulsification' International Journal of Pharmaceutics 2009; 377(1-2): 142-147.
24. Tadros T, Izquierdo P, Esquena J and Solans C: 'Formation and Stability of Nanoemulsions' Advances in Colloids and Interface Science 2004; 108-109: 303-318.
25. Aboofazeli R: 'Nanometric-Scaled Emulsions (Nanoemulsions)' Iranian Journal of Pharmaceutical Resaerch 2010; 9(4): 325-326.
26. Gurpret K and Singh SK: 'Review of Nanoemulsion Formulation and Characterization Techniques' Indian Journal of Pharmaceutical Sciences 2018; 80(5): 718-789.
27. Yu L, Li C, Xu J, Hao J and Dejun S: 'Highly Stable Concentrated Nanoemulsions by the Phase Inversion Composition Method at Elevated Temperature' Langmuir 2012; 28(14): 14547-14552.
28. Rutvij JP, Bharadia PD and Pandya VM: 'Nanoemulsion: An advanced Concept of Dosage Form' International J of Pharmaceutical Cosmetology' 2011; 1: 122-133.
29. Jaiswal M, Dudhe R and Sharma PK: 'Nanoemulsion: An Advanced Mode of Drug Delivery System' 3 Biotech, 2015; 5(2): 123-127.
30. Yadav J, Dhama J, Saxena N, Seema, SL N and Md Alam S: 'An Overview on Nanoemulsion' European Chemical Bullatein 2023; 12(8): 4876-4899.
31. Bouchemal K, Briancon S, Perrier E and Fessi H: 'Nano-emulsion formulation using spontaneous emulsification: solvent, oil and surfactant optimization. International Journal of Pharmaceutics 2004; 280(1-2): 241-251.
32. Lovelyn C and Attama AA: 'Current state of nanoemulsions in drug delivery. Journal of Biomaterials and Nanobiotechnology 2011; 2(5): 626-639.
33. Lifshitz IM and Slyozov VV: 'The kinetics of precipitation from supersaturated solid solutions. Journal of Physics and Chemistry of Solids 1961; 19: 35–50.
34. Wang Y: 'Preparation of nano and microemulsions using phase inversion and emulsion titration methods' master's thesis. Massey University, Auckland, New Zealand 2014.
35. Singh Y, Meher JG, Raval K, Khan FA, Chaurasia M, Jain NK and Chourasia MK: 'Nanoemulsion: concepts, development and applications in drug delivery. Journal of Controlled Release 2017; (252): 28-49.
36. Jayasooriya SD, Bhandari BR, Torley P and D'Arcy BR: 'Effect of high power ultrasound waves on properties of meat: a review. International Journal of Food Properties 2004; 7(2): 301-319.
37. Gaikwad SG and Pandit AB: 'Ultrasound Emulsification: Effect of Ultrasonic and Physicochemical Properties on Dispersed Phase Volume and Droplet Size' Ultrasonics Sonochemistry 2008; 15(4): 554-563.
38. Tiwari SB, Shenoy DB and Amiji MM: 'Nanoemulsion Formulations for Improved Oral Delivery of Poorly Soluble Drugs' Nano Science and Technology Institue 2006; (1): 475-478.
39. Ishak KA and Annuar MSM: 'Phase Inversion of Medium-chain-length Poly-3-hydroxyalkanoates (mcl-PHA)-incorporated Nanoemulsion: Effects of mcl-PHA Molecular Weight and Amount on its Mechanism' Colloid and Polymer Science 2016; 294(12): 1969-1981.
40. Armanet L and Hunkeler D: 'Phase inversion of Polyacrylamide-based inverse-emulsions: Influence of Inverting-Surfactant Type and Concentration' Journal of Applied Polymer Science 2007; 103(6): 3567-3584.
41. Vandamme TF and Anton N: 'Low-energy Nanoemulsification to Design Veterinary Controlled Drug Delivery Devices. International Journal of Nanomedicine 2010; 5(1): 867-873.
42. Solans C and Sole I: 'Nano-emulsions: Formation by Low-Energy Methods' Current Opinion Colloid & Interface Science 2012; 17(5): 246-254.
43. Fernandez P, Andre V, Rieger J and Kuhnle A: 'Nano-emulsion formation by emulsion phase inversion' colloids and surfaces. A Physicochemical and Engineering Aspects 2004; 125(1-2): 53-58.
44. Sharma S and Sarangdevot K: 'Nanoemulsions for Cosmetics' International Journal of Advanced Research in Pharmaceutical and Bio Sciences 2012; 1(3): 408-415.
45. Nielloud F: 'Current Galenical Research Challenges In Human Dermatology: Application for the Development of Products for Sensitive and Atopic Skin' Virbac Symposium 2003.
46. Kumari Ch. TL, Sowjanya GN and Bandhavi P: 'Nanoemulsions An Emerging Trend: A Review' International Journal of Pharmaceutical Research and Development 2012; 4(6): 137-152.
47. TPU Ravi and T Padma: 'Nanoemulsions for Drug Delivery through Different Routes' Research in Bio-Technology 2011; 2(3): 1-13.
48. Araujo, RG Kelmann, BV Araujo, RB Finatto, HF Teixeira and LS Koester: 'development and characterization of parenteral nanoemulsions containing thalidomide'. European Journal of Pharmaceutical Science 2011; 42(5): 238-245.
49. Kabri TH, Arab-Tehrany E, Belhaj N and Linder M: Physico-chemical characterization of nanoemulsions in cosmetic matrix enriched on omega-3'. Journal of Nano Biotechnology 2011; 9(41): 2-8.
50. Alia A. Badawi, Hanan M El-Laithy, Riad K El Qidra, Hala El Mofty and Mohamed El dally: 'Chitosan based nanocarriers for indomethacin ocular delivery'. Archives of Pharmacal Research 2008; 31(8): 1040-1049.
51. Ammar HO, Salama HA, Ghorab M and Mahmoud AA: 'Nanoemulsion as a potential ophthalmic delivery system for dorzolamide hydrochloride'. AAPS Pharmaceutical Science Technology 2009; 10(3): 808-819.
52. Koroleva M and Yurtov EV: 'Nanoemulsions: The properties, methods of preparation and promising applications. Russian Chemical Rev 2012; 81(1): 21-43.
53. Muller-Goymann CC: 'Physicochemical characterization of colloidal drug delivery systems such as reverse micelles, vesicles, liquid crystals and nanoparticles for topical administration'. European Journal of Pharmaceutics and Biopharmaceutics 2004; 58(2): 343-356.
54. Gaur PK, Mishra S, Purohit S and Dave K: 'Trans- dermal drug delivery system: A Review' Asian Journal of Pharmaceutical and Clinical Research 2009; 2(1): 14-20.
55. Devarajan V and Ravichandran V: 'Nanoemulsion: As Modified Drug Delivery Tool' International Journal of Comprehensive Pharmacy 2011; 2(4): 1.
56. Hoarau D, Delmas P, David S, Roux E and Leroux JC: 'Novel Long-circulating Lipid Nanocapsules, Pharmaceutical Research 2004; 21(10): 1783- 9.

57. Reza Hassan: 'Nanoemulsion as a novel transdermal drug delivery system. International Journal of Pharmaceutical Sciences and Research 2011; 2(8): 1938-1946.
58. Alton's pharmaceuticals: The Design and Manufacturing of Medicinie, 5 th Edition; Chapter 27; 470-473.
59. Craig DQM, Barker SA, Banning D and Booth SW: 'An investigation into the mechanisms of self-emulsification using particle size analysis and low frequency dielectric spectroscopy'. International Journal of Pharmaceutics 1995; 114(1): 103-10.
60. Chiesa M, Garg J, Kang YT and Chen G: 'Thermal conductivity and viscosity of water in oil nanoemulsions'. Colloids and Surfaces A: Physicochemical and Engineering Aspects 2008; 326(1-2): 67-72.
61. http;//www.pharmacast.com

How to cite this article:
Yadav S, Mishra P and Verma NK: Nanoemulsion: a carrier for drug delivery. Int J Pharm Sci & Res 2024; 15(7): 1914-28. doi: 10.13040/IJPSR.0975-8232.15(7).1914-28.