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Review

Preparation, Characterization and Applications of Nanoemulsions: An Insight

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ABSTRACT

Nanoemulsions are defined as isotropic, thermodynamically stable, transparent or translucent; dispersions of oil and water stabilized by surfactant molecules (forms an interfacial film) having the droplet size of 20-500nm. Ease of preparation and scale-up, stability and increased bioavailability are features of these formulations which have attracted the attention of researchers. Its basic principle lies in its ability to spontaneously generate fine o/w microemulsion under mild agitation following dilution with aqueous phases. These conditions mimic the digestive motility in the GIT necessary to provide the agitation required for *In vivo* self emulsification. Unlike emulsions, self-nanoemulsified drug delivery systems (SNEDDS) generates microemulsion with a narrow droplet size distribution of less than 50 nm due to which these systems have also been addressed as nanoemulsions. Nanoemulsions (NE) are lipidic nanoformulations with droplet diameter in nanometer range have established tremendous attention as drug delivery formulations for lipophilic drugs due to their capability to increase solubility, permeation across biological membranes as well as their therapeutic efficiency of lipid soluble drugs due to predictable size-distribution, high drug loading and stability under biological environment. However there is still relatively narrow insight regarding preparation, characterization and applications of nanoemulsions. This limitation unfolds the premise for current review article. In this review, we attempt to explore varying intricacies, methods of preparation, characteristics, and drug delivery applications of nanoemulsions to spike interest of those contemplating a foray in this field.

Keywords: Nanoemulsions, Novel drug delivery system, increased bioavailability.

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INTRODUCTION

A perfect formulation system achieves the goals of enhanced therapeutic response with least toxicity. By way of the progress and advancement in time, knowledge and tools, drug formulations have been enlarge from simple blend and tablets, to extremely complicated structure, which are famous as novel drug formulation systems. Drawbacks in intravenous administration such as extravasations of drug or blood, thrombosis and catheter infections can be prevented by administering the drug orally and thus making the oral drug delivery system the most accepted way of administration [1]. Though, oral drug deliverance is restricted by issues related to physico-chemical properties of the drug i.e. poor solubility, low intestinal permeability, instability in the harsh acidic environment followed by rapid metabolism, all of which decreases oral bioavailability [2].With the advancement in the drug design, various molecules have been created to facilitate a potential medicinal effect. But the majority of the recently discovered molecules or chemical molecules is of high molecular weight (Phytochemicals) and belongs to biopharmaceutical classification system (BCS) –IV, with low water solubility and low intestinal permeation property. Hence these properties limit the bioavailability of orally administered drugs [3]. This poor aqueous solubility not simply gives the low oral bioavailability of drug but also leads to elevate inter and intra matter inconsistency and lack in amount proportionality [4]. Various techniques like micronization, complexation, solid dispersion and permeation improver with surfactant have been cited to overcome low solubility and intestinal permeation issues [5]. In this era, Nanoformulations has brought a revolution in creating devices with novel concepts and in drug delivery systems. Recently, many "lipid based formulations (solid lipid nanoparticles, nanostructured lipid carriers", nanoemulsion and liposomes) have been investigated to overcome the bioavailability issues associated with the oral administration of drugs [6]. Avoidance of first pass metabolism of drug, improve mucosal adhesion, improved permeation across the intestinal membrane barrier,

protection against harsh GI environment and controlled release are major mechanisms which further enhance the bioavailability, effectiveness of phyto-medicines as well as their tunable release profile in blood circulation. Besides that, lymphatic system "plays an essential role in absorption of long chain fatty acids, triglyceride, cholesterol, esters, lipid soluble vitamins and xenobiotic" [7, 8]. Nanoemulsions (NE) are lipidic nanoformulations with droplet diameter in nanometer range have established tremendous attention as drug delivery formulations for lipophilic drugs due to their capability to increase solubility, permeation across biological membranes as well as their therapeutic efficiency of lipid soluble drugs due to predictable size-distribution, high drug loading and stability under biological environment [9, 10]. O/W Nanoemulsions possesses a core shell assembly wherein core shell acts as a pool for the assimilation of poorly water soluble drugs and hydrophilic shell provides a protective interface between the core and the external medium [11, 12].

WHAT ARE NANOEMULSIONS

Nanoemulsions are defined as isotropic, thermodynamically stable, transparent or translucent; dispersions of oil and water stabilized by surfactant molecules (forms an interfacial film) having the droplet size of 20-500nm [13]. Ease of preparation and scale-up, stability and increased bioavailability are features of these formulations which have attracted the attention of researchers [14, 15].

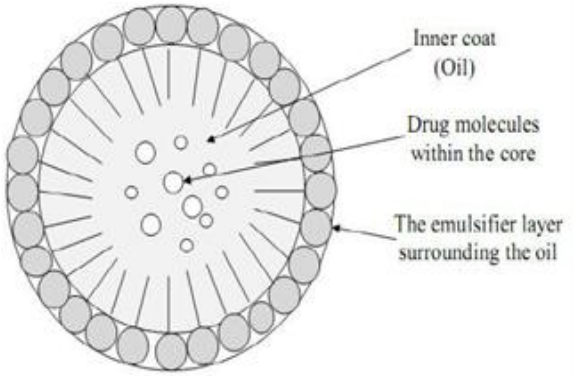

Figure 1: Structure of Nanoemulsion droplet

Its basic principle lies in its ability to spontaneously generate fine o/w microemulsion under mild agitation following dilution with aqueous phases. These conditions mimic the digestive motility in the GIT necessary to provide the agitation required for *In vivo* self emulsification. Unlike emulsions, self-nanoemulsified drug delivery systems (SNEDDS) generates microemulsion with a narrow droplet size distribution of less than 50 nm due to which these systems have also been addressed as nanoemulsions. The fine droplets of this dosage form have the advantage of presenting the drug in a dissolved form with an increase interfacial area which helps in the better absorption of the drug which results in more uniform and reproducible bioavailability. Moreover, it has also observed that the drug is maintained in the dissolved state throughout the GIT which helps in enhancing the bioavailability of PWSD. In addition, the fine droplets offer large surface area for pancreatic lipase to hydrolyze the lipids and therefore enhance the rate of drug release. The adequate solubility of the drug in the lipid/surfactants blend, nature of the lipid/surfactant pair, the ratio between the lipid and the surfactant, the surfactant concentration and the uniform droplet size distribution following self-emulsification are necessary components to be monitored during the development of SMEDDS [13, 16, 17].

ADVANTAGES OF NANOEMULSION

- Nanoemulsion is one of the best approaches to increase water solubility of the lipophilic drugs, which in turns increases the bioavailability of the drug in the systemic circulation. As the droplets are in nano size it is having increased interfacial areas it effects the transport properties of the drug, which is an very important factor in drug delivery (sustained and targeted) [13, 14].
- Plasma concentration profiles and bioavailability are more reproducible when the drugs are administered in nanoemulsion formulation [18, 14].
- It has been observed that as the oil droplets are fine, it empty quickly from the stomach and increase proper distribution of the API throughout the intestinal tract. By doing so it minimizes irritation frequently observed with long contact of the drug and gut wall [13, 19].
- Nanoemulsions based formulations are having higher capacity of solubilization than formulation based on simple micellar solutions. Nanoemulsions are also thermodynamically stable which offer advantage over emulsions and suspensions those are unstable dispersion system. Nanoemulsions can easily prepared by little energy input that is by less heat and mixing and it also has long shelf life [14].
- They also provide ultra low interfacial tension and large o/w interfacial areas [14, 20, 21].
- They also offer an advantage over existing self-emulsifying system in terms of rapid onset of action (no extra time for dispersion) and reduced inter subject variability in terms of GIT fluid volume.
- Nanoemulsions may possess high kinetic stability and optical transparency resembling to microemulsions [18, 22].
- The structures in the nanoemulsions are much smaller than the visible wavelength, so most nanoemulsions appear optically transparent, even at large loading [13, 18, 23].
- Nanoemulsions are also used to deliver peptides that easily undergo enzymatic hydrolysis (degradation) in GIT [14, 24, 25].

MAJOR COMPONENTS OF NANOEMULSION

Oils: Selection of an appropriate oily phase is very important as it influences the selection of other ingredients of nanoemulsions, mainly in case of O/W nanoemulsions. Usually, the oil which has maximum solubilising potential for selected drug candidate is selected as an oily phase for the formulation of nanoemulsions. This helps to achieve maximum drug loading in the nanoemulsions [17, 21]. Composition of naturally occurring oils and fats are mixtures of triglycerides. These triglycerides are consists of fatty acids (which have varying length of the chain and the extent of unsaturation). Triglycerides are classified as short (<5 carbons), medium (6-12 carbons), or long chain (>12 carbons) and may be synthetically hydrogenated to decrease the degree of unsaturation, thereby conferring resistance to oxidative degradation. The choice of oily phase is often a compromise between its ability to solubilize the drugs and its ability to facilitate formation of nanoemulsion of desired characteristics. Thus mixture of oils can be used to meet both the requirements. For example, a mixture of fixed oil and medium chain triglycerides is used to have good balance between drug loading and emulsification [22]. Triglyceride oils (both long and medium chain) with different degrees of saturation can

be used to formulate SMEDDS. Triglycerides are highly lipophilic and their solvent capacity for drugs is commonly a function of the effective concentration of ester groups, thus on weight basis medium chain triglycerides (MCT) have higher solvent capacity and resistance to oxidation compare to long chain triglycerides [17]. Modified vegetable oils, oils and fats (digestible or non-digestible) such as palm oil, olive oil, corn oil, sesame oil, oleic acid, hydrogenated soybean oil, peanut oil, soybean oil and beeswax are also used as oil phase in nanoemulsion formulation [16].

Surfactants: The surfactant should favour microemulsification of the oily phase and should also possess good solubilising potential for the hydrophobic drug compounds. The choice of the surfactant is critical for the nanoemulsion formulation. Surfactants with an HLB value <10 are hydrophobic (such as sorbitan monoesters) and form w/o nanoemulsion where as high HLB (>10) surfactants such as polysorbate 80 are hydrophilic and form o/w nanoemulsion. In many cases, mixture of lipophilic (low HLB) and hydrophilic surfactants (high HLB) may be required to obtain nanoemulsion [21]. Below critical micellar concentration (CMC) of the surfactant in solution it increases drug solubility by giving regions for lipophilic drug interactions in solution. Above CMC, surfactants aggregate to form micelles with the lipophilic core and a lipophobic surface. The lipophilic core of the micelles influence the entrapment of drug (mostly lipophilic in nature), thus increasing its solubility. It has seen that when the content of the oil is more, surfactant concentrate on interface of the oil/water forming emulsions, where the lipophilic drug is solubilized inside the internal hydrophobic core. On the other hand when the oil content is low, minute oil-entrapped surfactant globules are produced, which are known as nanoemulsions [21]. The surfactant used in nanoemulsion formation could be ionic or non-ionic but ionic surfactants are not preferred due to toxicological concerns. Non-ionic water soluble surfactants are commonly used for SMEDDS formulation. Among various surfactants that are available, lecithins, poloxamers and polysorbate 80 are most preferred. The usual surfactant concentration in SMEDDS formation and maintaining emulsion stage ranges from 30-60% w/w of the formulation. Concentration of the surfactant in the formulation should be determined properly as it is very while formulating nanoemulsion. It has been observed that high concentration of surfactants cause GI irritation. Relation between the size of the droplet and concentration of the surfactant should be realized properly. In some instances, when there is an increase of the surfactant concentration it lead to formulation of smaller droplets of the oil. This type of behavior has been observed in case of a mixture of saturated C8-C10 polyglycolized glycerides. This is due to the localization of the surfactants at the oil-water interface which stabiles the formulation. Sometimes it has also observed that the mean droplet size of the oil globules may increase with the increase of surfactant concentration [21, 26].

Co-surfactants: Most of the times, surfactant alone cannot lower theoil-water interfacial tension sufficiently to yield a nanoemulsion which necessitates the addition of an amphiphillic short chain molecule or cosurfactant to bring about the surface tension close to zero. Cosurfactants penetrate into the surfactant monolayer providing additional fluidity to interfacial film and thus disrupting the liquid crystalline phases which are formed when surfactant film is too rigid [21]. Usually a very low HLB cosurfactant is used with a high HLB surfactant to modify the overall HLB of the system. Unlike surfactant, the cosurfactant may not be capable of forming self-associated structures like micelles on its own. Hydrophilic cosurfactants preferably alcohols of intermediate chain length such as hexanol, pentanol and octanol, which are known to reduce the oil/water interface and allow the spontaneous formation of nanoemulsion [16, 18].

Co-solvents: Production of an optimum nanoemulsion requires a highconcentration of surfactants, that is generally more than 30% w/w. Various organic solvents like glycerol, polyethylene glycol(PEG), ethanol, propylene glycol (PG) are used for oral delivery of the drug, and this cosolvents are having efficacy to dissolve large amount of water soluble surfactant or the API in the lipid base. Mostly it makes the environment more lipophilic by decreasing the dielectric constant of aqueous phase [18]. There are some cosolvents like alcohols and other volatile substances have disadvantage of evaporating into the soft gelatin or hard gelatin capsules shells of the in conventional SMEDDS which leading to precipitation of drug. Thus, formulation should be free from alcohol while designing [18, 21, 27].

METHODS OF PREPARATION OF NANOEMULSIONS

Nanoemulsions are made from various excipients like surfactants those are approved for internal human use and some food materials 'Generally Recognized as Safe' by the Food and Drug Administartion. Nanoemulsions can be easily produced in large quantities by mixing aqueous phase with a water-immiscible oil phase using a process called high-stress, mechanical extrusion, which is easily available. As nanoemulsions are having very small droplet size, it can be effectively prepared by high-pressure equipment. Mostly equipments used for the formulation of the nanoemulsion are:

a. High-pressure homogenization and

b. Microfluidization

Both the equipments can be used for laboratory as well as industrial scale.

Other methods are also used in the formulation of nanoemulsion like, Ultrasonification and spontaneous emulsification which are also suitable for laboratory scale and not used for the commercial production [14, 21, 28].

Table 1: Different techniques employed for preparation of Nanoemulsions

Technique	Formulation	Conclusions	Ref
High pressure homogenization	Oral lipid nanoemulsion (primaquine)	Enhanced oral bioavailability, 10-200 nm particle size	29
Pseudoternary phase diagram + spontaneous emulsification method	Ramipril nanoemulsion	Increased bioavailability, droplet size 80.9 nm	30
High pressure homogenization	O/W nanoemulsions	Improved skin hydration and elasticity	31
Spontaneous emulsification	O/W nanoemulsion (aceclofenac)	Nanoemulsion with potential for transdermal delivery of aceclofenac	32
Spontaneous emulsification	Celecoxib nanoemulsion	Enhanced physical and chemical stability of celecoxib in nanoemulsion	33
High pressure homogenization	Lecithin-based nanoemulsions (progesterone)	Improved permeation rates of progesterone with long-term stability	34
High pressure homogenization	Prednicarbate nanoemulsion	Increased chemical stability of the drug in formulation	35
Phase inversion temperature method	Acyclovir-loaded multiple W/O/W nanoemulsions	Excellent physicochemical stability for 6 mo at RT, mean droplet size of 100 nm	36
Spontaneous nanoemulsification method	Clotrimazole nanoemulsion	Improved solubility of clotrimazole, mean globule size <25 nm	37
Ultrasonic emulsification method	Basil oil nanoemulsion	Nanoemulsions with droplet size of 29.6 nm, for food preservation	38
High-pressure homogenizer	Dimethyl silicone dry nanoemulsion inhalation	Effective in acute lung injury, particle size of 19.8 nm	39
Microfluidization method	Pitavastatin-containing nanoemulsions	Enhanced permeation	40
High-pressure homogenization+ ultrasound	Nanoemulsion	Reduced energy demand for emulsification, low particle dimensions and higher stability	41
Sonication method	Saponin-stabilized quercetin-loaded o/w nanoemulsion	Stable for 45 d at RT, mean particle size of 52±10 nm	42
High-pressure homogenization	Paclitaxel-baicalein nanoemulsion	Strategy to overcome multidrug resistance	43
Nanoemulsion templating	PLGA nanoparticles	Imaging agents for biomedical purposes	44
Spontaneous emulsification method	Chitosan films with cinnamaldehyde nanoemulsions	Good UV barrier properties	45

CHARACTERIZATION OF NANOEMULSIONS

The prepared nanoemulsions are evaluated for following parameters:

Dye Solubilization [46]

A water soluble dye is solubilized within the aqueous phase of the w/o globule but is dispersible in the o/w globule. An oil soluble dye is solubilized within the oil phase of the o/w globule but is dispersible in the w/o globule.

Measurment of Droplet Size and Polydispersity Index

The mean particle size and polydispersity index are measured at 25^0C by dynamic light scattering (DLS) using a Malvern Zetasizer. The size of the particles is measured by using disposable capillary cuvette equipped with electrodes. To avoid multiple scattering effects in the measurements, samples are diluted 100-fold with double-distilled water immediately before measurement [47]. The droplet size and poly dispersity index of the investigated samples is obtained (in triplicate) by calculating the average of 13 measurements at an angle of 173^0 [48, 49].

Interfacial Tension [50]: By measuring the interfacial tension the properties of nanoemulsion can be studied and Spinning-drop apparatus can be used to measure the ultra low interfacial tension. Interfacial tensions are derived from the measurement of the shape of a drop of the low-density phase, rotating it in cylindrical capillary filled with high-density phase.

Particle Size Analysis: For the measurement of particle size and their distribution dynamic light scattering (DLS) method is generally used in case of nanoemulsion [51].

Conductance Measurement [46]

Conductance measurements are usually carried out to determine the nature of the continuous phase and to detect phase inversion phenomena; the electrical conductivity measurements are highly useful. In o/w nanoemulsion where the external phase is water, are highly conducting whereas w/o are not, since water is the internal or dispersed phase. Dielectric measurements are a powerful means of probing both structural and dynamic features of nanoemulsion systems.

Refractive Index: Refractive index of nanoemulsion is determined by using an Abbes type refractometer. The refractive index of each sample measured three times, and mean value and standard deviation (SD) are calculated [52].

Viscosity [53]

The viscosity of the nanoemulsions is measured by Brookfield viscometer and the spindle size of 62 and rpm 60 is used for the study and the viscosity is expressed in terms of centipoises.

Percent Drug Loading: To determine percent drug loading, pre-weighed nanoemulsion is extracted by dissolving in 25ml suitable solvent, then the extract is analyzed spectrophotometrically/ by using HPLC against the standard solution of drug. Drug content is determined by reverse phase HPLC method using different columns of appropriate porosity [54].

Determination of Entrapment Efficiency [55]: Entrapment efficiency (EE %) is determined by measuring the concentration of free drug (un-entrapped) in aqueous medium. This is the prime importance, as it influences the release characteristics of drug molecule. The amount of

drug encapsulated per unit weight of nanoformulation is determined after separation of the entrapped drug from the nanoemulsion formulation. The entrapment efficiency is determined by following formula:

$$EE = \frac{Wt\ of\ total\ drug\ in\ formulation - Wt\ of\ drug\ in\ aq.phase}{Wt\ of\ total\ drug\ in\ formulation} \times 100$$

***In Vitro* Permeation Studies [56]:** *In vitro* skin permeation studies are carried out on abdominal skins obtained from male rats weighing 250±10 g by using Keshary Chien-diffusion cell. The skin is placed between the donor and the receptor chamber of vertical diffusion cell. The receptor chamber is filled with fresh water containing 20% ethanol. The temperature of the receiver chamber is set at 37°C and the solution in the receptor chamber is stirred continuously at 300 rpm. The formulations are placed in the donor chamber and the solution in the receiver chamber is removed at different time intervals for GC analysis and replaced immediately with an equal volume of fresh solution. Each sample is performed three times .The cumulative corrections are made to obtain the total amounts of drugs permeated at each time interval. The cumulative amounts of drug permeated through rat skins are plotted as a function of time. The permeation rates of drug at a steady-state through rat skins are calculated from the slope of linear portion of the cumulative amount of drug permeated through the rat skins per unit area versus time plot.

Stability studies [53]

For the evaluation of nanoemulsions, the stability study is an important criterion to be considered. Nanoemulsions are characterized by its high stability than the other dispersed systems. The various stability studies conducted for nanoemulsions include:

a) Thermodynamic stability studies, and
b) Accelerated stability studies.

a. Thermodynamic stability studies

In Thermodynamic stability studies the selected formulations are subjected to different thermodynamic stability studies tests to assess their physical stability [57]. The process involved 3 cycles, initially heating and cooling cycles are carried out 6 times, followed by alternately heating and cooling at 40°C and 4°C respectively, this is followed by centrifugation at 3500 rpm for 30 min. Each cycle is observed for changes in the formulation due to phase separation.

b. Accelerated stability studies

Accelerated stability studies are performed on optimized formulation. Three batches of the nanoemulsions are taken in glass vials and were kept at a temperature of 30°C, 40°C, and 60°C at ambient humidity condition [58]. The samples are withdrawn for studying drug content as per standard procedure mentioned in International Conference on Harmonisation (ICH) Q1 guidelines. The amount of the drug degraded at each time interval is calculated nand order of the reaction is determined by graphical method. The degradation rate constant (K) is determined for each temperature.

APPLICATIONS OF NANOEMULSIONS IN VARIOUS FIELDS

1. Nanoemulsions in drug delivery

Nanoemulsions have been used in most topical, ocular, intravenous, internasal and oral drug delivery. These applications influence the lyphophilic nature of nanoemulsions to solvate water-insoluble drugs; and tunable charge and rheology of nanoemulsions to formulate aqueous solutions that can be easily delivered to patient. Though skin protects us from the external environment, it also acts as a transport barrier against administration of drugs through the skin. Topical medication formulated using nanoemulsions can provide unique advantages as the dispersed phase of O/W nanoemulsions enables enhanced solubility of lipophilic drugs in the oil phase and the continuous phase provides a mild, skin-friendly environment that can dissolve biopolymers such as alginate for adjusting the formulation rheology, appearance and texture. A considerable number of studies focused on using nanoemulsions for topical drug delivery. Few of the above-mentioned studies included permeation tests to evaluate the effectiveness of topical delivery. Some studies claim that owing to the relatively small size and low z-potential of nanoemulsion formulations, hydrophobic drugs are delivered more efficiently than are suspensions of these drugs [59].

Mou et al. prepared hydrogel thickened nanoemulsions that had higher permeation rates as compared to conventional hydrogels [60]. Researchers have also explored the use of nanoemulsions in other modes of drug delivery such as ocular, intravenous, intranasal and oral delivery. Nanoemulsions have also been used as ultrasound imaging agents [61]. Kaneda et al. prepared nanoemulsions containing perfluorocarbons for quantitative molecular imaging and targeted therapeutics [62]. Gianella et al., [63] engineered a multifunctional nanoemulsion based platform to enable an imaging-guided therapy. Researchers evaluated the utility of the platform in a colon cancer mouse model. In this study, oil-in-water nanoemulsions carried iron oxide nanocrystals for MRI, the fluorescent dye Cy7 for NIRF imaging, and the hydrophobic glucocorticoid prednisolone acetate valerate for therapeutic purposes.

II. Nanoemulsions in Biotechnology [64]

Many enzymatic and biocatalytic reactions are conducted in pure organic or aqua-organic media. Biphasic media are also used for these types of reactions. The use of pure a polar media causes the denaturation of biocatalysts and the use of water-proof media is relatively advantageous. Enzymes in low water content display and have;

- Enhanced solubility in non-polar reactants.
- Possibility of shifting thermodynamic equilibria in favour of condensations.
- Improvement of thermal stability of the enzymes, thus enabling reactions to be carried out at higher temperatures.

Many enzymes including lipases, esterases, dehydrogenases and oxidases often function in the cells in microenvironments that are hydrophobic in nature. In biological systems many enzymes operate at the interface between hydrophobic and hydrophilic domains and these usually interfaces are stabilized by polar lipids and other natural amphiles. Enzymatic catalysis in nanoemulsions has been used for a variety of rxns, such as peptides and sugar acetals transesterification, synthesis of esters and steroid transformation. Lipases are the most commonly used class of enzymes [65].

III. Nanoemulsions in Cosmeticology

Nanoemulsion is used as vehicle for controlled delivery and as effective transport vehicle. The Kemira Nanogel nanoemulsion based carrier system is a patented system for cosmetic purpose which enhances skin production and

penetration of API. Apart from that it also provide good skin feel [66]. Topical administration itself has many advantages and by combining it with nanoemulsion, this formulatory may impart the better way of drug delivery system. It can bypass the hepatic first pass metabolism of the drug and related toxicity effects [67].

IV. Nanoemulsions in Food industry

Nanoemulsions offer a wide range of applications due to their compositional flexibility in various fields including food and beverage industries. As compared to microemulsions, nanoemulsions have found a lot of applications in food processing due to its very small size, thermodynamic stability, continuous self-assembly with hydrophilic and hydrophobic portion, transparency and weak light wave scattering capacity, which eventually lead to their incorporation into optically transparent products such as fortified soft drinks and waters. Disparate micro or other conventional emulsions, nanoemulsions can be prepared to be more viscous or gel-like with very low droplet concentrations, which can be easily used to make products with low fats and novel texture [68]. Nanoemulsions can enhance the shelf-life of industrial products due to the stability of the droplet of the nanoemulsion, stability to particle aggregation and gravitational separation. Joe et al. used nanoemulsions prepared from sunflower oil for the processing of Indo-Pacific king mackerel steaks and observed no microbial growth up to 12 h and the shelf life of the product was increased up to 48 h [69].

CONCLUSION

This review focuses on nanoemulsions as drug delivery vehicle. Nanoemulsion formulations show numerous advantages for the delivery of drugs, biological or diagnostic agents and are able to protect labile drug, increase drug solubility, enhance bioavailability, control drug release and reduce patient variability. Moreover, nanoemulsions have been used traditionally in clinics for more than four decades as total parenteral nutrition fluids. In recent years nanoemulsions with droplet size of less than 100 nm have drawn great attention because of their potential applications in pharmaceutical, cosmetics, biotechnology and food industries as a better delivery system due to their small droplet size, transparency, and high kinetic stability. But still there is need to emphasize on toxicological evaluation of the prepared nanoemulsions, which can be a wide area of research in future.

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