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REVIEW ARTICLE

Potential Future Perspectives of Emulgels: Emphasizing their Role in Addressing Contemporary Challenges in Drug Delivery and Skincare

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Abstract

Emulgel formulations have emerged as a prominent category in pharmaceutical and cosmetic industries due to their unique characteristics combining the properties of emulsions and gels. This comprehensive review paper delves into the world of emulgels, focusing on their emulsion-based preparation and lipophilic nature. We explore the classification of emulgels, detailing the various types and their applications. This paper provides a comprehensive overview of various techniques employed in the preparation of emulgels. The focus is on elucidating the intricacies involved in achieving formulations that are both stable and efficacious. The diverse methods discussed in the paper shed light on the nuanced aspects of emulgel preparation, offering valuable insights for researchers and practitioners in the field. Moreover, we present a compelling rationale for the adoption of emulgels as a novel drug delivery system, highlighting their ability to enhance drug infiltration, stability, and patient compliance. In addition to a retrospective analysis, this review paper provides insights into the current landscape of emulgels, covering recent advancements and applications across pharmaceuticals and cosmetics. Furthermore, we discuss the potential future perspectives of emulgels, emphasizing their role in addressing contemporary challenges in drug delivery and skincare. This review serves as a valuable resource for researchers, practitioners, and industry professionals interested in harnessing the potential of emulgels for innovative formulations and therapeutic applications.

Keywords: Emulgel, Emulsion, Emulsifier, Gelling Agent, Topical Drug Delivery

1. Introduction

Emulgel is a hybrid pharmaceutical formulation combining the properties of both an emulsion and a gel. This versatile combination offers a stable and efficient platform for delivering active ingredients, commonly used in topical applications for enhanced drug absorption and therapeutic effects[1] potential advantages and drawbacks of various conventional techniques and the newer approaches specifically the self-emulsifying systems are discussed. Various components of the self-emulsifying systems and their selection criteria are critically reviewed. The attempts of various scientists to transform the liquid self-emulsifying drug delivery systems (SEDDS). Oral delivery of these molecules is challenging because of their low and inconsistent bioavailability, along with difficulties in achieving accurate dose proportionality[2]. Regardless of the delivery route, improving the Lipophilic compounds' bioavailability drugs is a crucial problem[3].

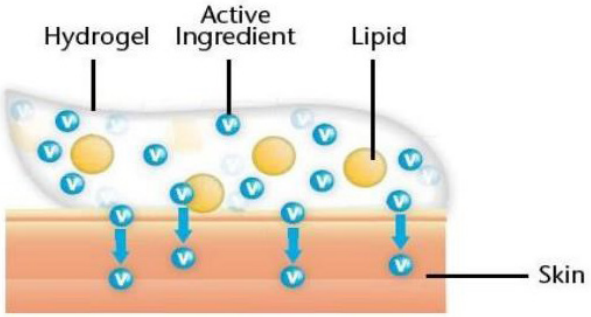

Figure 1. Structure of Emulgel[4].

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The structure of an emulgel typically consists of a water-in-oil (w/o) or oil-in-water (o/w) emulsion embedded within a gel matrix as shown in Figure 1[4]. This combination imparts stability and ease of application to the formulation. The gel component contributes viscosity and rheological properties, while the emulsion enhances drug absorption and bioavailability. The gel component provides the emulgel with its characteristic rheological properties, ensuring ease of application and improved stability. This dual-phase structure allows for controlled drug release, enhanced topical absorption, and an overall effective delivery system for various pharmaceutical and cosmetic applications[5].

Here is a review, we aim to summarize also discuss some outcomes of various research into permeability, pharmacokinetics, pharmacodynamics, in addition safety record of medications administered topically nanoemulgels. We also evaluate the rationality of their use and highlight the primary obstacles that need in an effort to be conquer for successful formulation for nanoemulgel. While several review articles on nanoemulgels are available, our review critically evaluates the reason and the future prospects of the medication delivery mechanism, comparing Permeation *in vitro/in vivo,* pharmacokinetics, pharmacodynamics, profile of safety, and significant obstacles. Examined here stands as the unique in its sort, making a unquestionably significant to enhancing knowledge in the technology for pharmaceuticals, in particular nanotechnology[6].

Over the course of many years, human beings have encountered several different illnesses that affect their wellbeing and health. Efforts to remedy these disorders have led to the finding of different Substances, medicines, and mechanism of providing. In order toward achieve the necessary therapeutic reaction needed for the therapy for a several administration methods are used for diseases, depending on this type and severity form the disorder. The method of administration through the topical route entails often desired for skin disorders. Cutaneous medication delivery involves directly applying a use of a skin-care product containing medicine achieve a specific result[7].

Administration of drugs topically systems offer various benefits, including the delivering capacity drugs specifically to a particular location, avoiding metabolic breakdown and compatibility issues with the digestive system associated with oral administration[8]. Furthermore, prompt delivery provides higher bioavailability as a result of by passing preliminary metabolism in the hepatic and allows for uniform delivering drugs over an prolonged period[9,10]. During this system, the drug permeates from the delivery system, arrives at the intended target location, and is taken in by the skin[11] the penetration flux (Js. Improving a release rate of the medication from the dose form can enhance absorbed through the skin[12].

Emulsion gels have been utilized since the middle of the 1980s and gained significance in topical semisolid pharmaceutical dosage formulations. These systemic hydrophilia, which can be o/w, w/o emulsions, are mixed to create a gel with a gelling agent[13]. Emulgel serves as regulated release systems, drug particles entrapped into the external phase pass via the internal phase to the skin where they are gradually absorbed. Internal stages serve as reservoirs regarding the substance, providing regulated release through the exterior stage. A gel matrix of emulgels takes in tiny drug particles and facilitates controlled release. Emulgel formulations possess mucoadhesive properties, prolonging the duration of medication contact with skin[14]. Being a mixture of emulsions as well as gel, emulgels serves as mechanism with two regulated releases[15]. (w/o) emulsions are frequently used to treat dry skin and as emollients, whilst (o/w) emulsions are advantageous as medication bases that can be easily washed with water and for aesthetic purposes in general[9,14,16]. Any topical preparation's effectiveness depends on its capacity for penetration, which is defined as the ability to remove oil or substances from the skin. Emulsions that exhibit thixotropic behavior, i.e., becoming during shearing, become less viscous, simplify the procedure of penetration within the skin. Incorporating emulsions into gels can improve their stability and penetration ability. Dermatological gels have several favorable properties, including thixotropy, non-greasiness, ease of spreadability, ease of removal, emollience, non-staining, compatibility with various water and excipients solubility or miscibility[15,17]. The stability and release rate of the medicine could be influenced by the type and concentration of the polymer used in the gel matrix[7,18-20].

Despite the advantages of emulgels, there are some limitations, during formulation, bubbles were trapped and macroparticles were poorly absorbed

through the skin[21]. Emulgels are well accepted by patients due to their non-greasy nature and ease of application contrasted to other topically applied substances like oily, thick lotions and ointments that demand a lot of rubbing[22-25]. In the development of new drugs, scientists face challenges when dealing with drugs that have poor solubility, which can come the biopharmaceutical classification system categorizes drugs into four groups based on data regarding their solubility *in vitro* and permeability *in vivo*. In this classification, Class II drugs, which are characterized by low solubility but high permeability, are primarily constrained by their reduced capacity to dissolve. This aspect significantly affects absorption rate and extent more than their ability to cross membranes[26,27] there is no satisfactory treatment available for the vast majority of patients and the exploration of gene therapeutic approaches is highly warranted. However, mitochondrial gene therapy still appears only theoretical and speculative. Any possibility for gene replacement depends on the use of a yet unavailable mitochondria-specific transfection vector. Mitochondria-specific vectors must posses two properties: they have to transport DNA to the side of mitochondria; they must not release DNA during endocytosis. Amphiphile compounds with delocalized cationic charge centers such as rhodamine 123 and the bola-amphiphile dequalinium have long been known to accumulate in mitochondria. Sufficient lipophilicity combined with delocalization of the positive charge to reduce the free energy change when moving from an aqueous to a hydrophobic environment are believed to be prerequisite for mitochondrial accumulation in response to the mitochondrial membrane potential. We have recently succeeded in preparing cationic vesicles made of dequalinium that we termed DQAsomes.

2. Classification

The emulgel is based on three categories.

These categories are as follows:

- The first category comprises emulsion gels that are protein-based.
- The second category consists of emulsion gels that rely on polysaccharides.
- The third category involves mixed emulsion gels[28].

The detailed classification of emulgels is given in Table 1.

Table 1. Classification of emulgels

S. No.	Emulgel			
	A	**B**	**C**	**Reference**
	Protein Emulgels	Polysaccharide Emulgels	Mixed Emulgels	[29]
1	Casein	Alginate	Protein-protein	
2	Gelatin	Carrageenan	Polysaccharide-polysaccharide	
3	Soy protein	Gums	Protein-polysaccharide	
4	Whey protein	Starches	Protein-protein-polysaccharide	

2.1 Protein based Emulgel

Emulsion gels often have a higher protein concentration in the gel part. Biopolymers like caseins, gelatin, soy proteins, and whey proteins are commonly used to make these gels. These biopolymers are preferred because they come from abundant and renewable sources and have properties that are good for making emulsions and gels. Different methods, including heating and cold methods like adding acid, ethanol, enzymes, salt, or hydrostatic pressure, are used to make protein conjugated gel[30,31].

Recently researcher conducted a study exploring the creation of whey protein emulsions converted into nanogel particles, measuring between 0.45 μm and 0.55 μm. By optimizing the formulation with whey protein, soybean oil, and capsaicinoids, their research demonstrated that emulgel significantly improved bioavailability of encapsulated capsaicinoids during *in vitro* testing, with increased release correlating directly with the degree of lipid digestion[32].

Fu *et al.*, added Medium-chain lipids and cinnamaldehyde oils to whey protein emulgel, inducing cross-linking observed through scanning electron microscopy, resulting in reduced viscosity, enhanced viscoelasticity, and uniform pore formation; subsequent laboratory experiments revealed slower breakdown of protein-dominant gels compared to those with cinnamaldehyde, suggesting cinnamaldehyde's softening effect accelerated the disintegration of the latter formulation in the gastrointestinal system[33].

Lv *et al*., aimed to encapsulate curcumin using whey protein isolate-stabilized gelled canola oil, achieving a high loading capacity of 90.3%. Because of its dense, solidified structure of the final gels. *In vitro* release tests revealed that the emulsion gel, with its gel-like structure offering increased resistance to pepsin hydrolysis, exhibited a slower release rate compared to the liquid emulsion, providing significant protection against degradation and remarkable stability during 240 minutes of storage under light conditions, retaining over 70% of the initial amount, in contrast to only 7% in the control group without protection[34]. Tan and colleagues created concentrated emulsion gels for nutraceutical transport by encapsulating 80% sunflower oil with gelatin particles, about 200 nm in size, as emulsifiers, demonstrating exceptional stability for more than 90 days of storage. The gel, encapsulating Beta-carotene within another substance, demonstrated a remarkable 90% retention rate, surpassing the bulk oil's 27-day retention rate of only 8% for β-carotene[35,36].

2.2 Based on Polysaccharide

This emulgel is composed of large carbohydrate molecule food polymers that possess gelation properties, which are determined by their source and structure. Emulgels consist of carbohydrate food polymers like alginate, agarose, and xanthan gum, with gelation induced through methods like heating, cooling, pH adjustment, and the addition of ions or salts[31,37]. Emulsion gels based on polysaccharides are known for their thermo reversible properties, and the colloidal particles derived from them are considered fewer effective emulsifiers for producing emulgel compared to protein conjugated emulgel. Protein-conjugated emulgel, on the other hand, exhibits long-term stability due to the presence of protein molecules that not only serve as gel substrates but also act as excellent stabilizers[29,36,38]. On the other hand, biopolymers derived from polysaccharides are highly adept at boosting viscosity and exhibit natural resilience against digestive enzymes. These traits render them ideal candidates for transporting bioactive compounds that necessitate an extended passage through the digestive system for the encapsulated substances[39-42]. Researcher investigated starch-containing emulgel formed via thermal gel formation, revealing that a 20 wt% starch concentration and 5–15 wt% oil content resulted in a 50% increase in gel elastic modulus, attributed to hydrophobic interactions and hydrogen bonding. Additionally, gel particles of 5–50 μm diameter were produced through top-down shearing, suggesting potential applications for delivering active compound in diverse consumables and grooming essentials[43]. Mokhtari *et al*., developed alginate nano polymer gels for efficient nutraceutical delivery using emulsification and calcium chloride-induced internal gelation. Optimized concentrations of sodium alginate, canola oil, calcium chloride, and Tween 80 produced spherical nanocarriers, with increased alginate content enhancing encapsulation efficiency due to higher viscosity and improved cohesion properties[44]. The study found that when curcumin was in the crosslinked emulsion gel, it was harder for enzymes to move around, reducing how much of the curcumin could be absorbed. However, the curcumin mixed into the crosslinked emulsion showed better resistance to light and heat, with most of it staying intact even after being exposed to light and heat, which was better than in the non-crosslinked systems[45]. Researchers, notably Le *et al*., have shown growing interest in mixed gels due to their superior control over physicochemical properties compared to individual emugel. Le *et al*., discovered that when proteins and polysaccharides are mixed together, they create gels that can hold a lot of water. These gels can hold up to 600 times their weight in water and can form different tiny structures to give the desired texture[40]. While the homogenization, the presence of polysaccharides in mixed gels imparts improved resistance to different environmental factors like pH levels, temperature fluctuations, and ionic strength. This enhanced stability ensures that the gel structure remains intact and unaffected by changes in these factors. On the other hand, the protein component of mixed gels exhibits excellent emulsifying capacity, leading to the formation of smaller droplet sizes during the emulsification process. This contributes to the creation of a homogenous gel structure with uniformly distributed droplets throughout[38]. Different techniques can be used to create mixed emulgel, such as heating, cooling,etc[40,46]. Coacervation is a widely used method for creating mixed gels, particularly when employing oppositely charged biopolymers. This technique involves controlling various factors such as the ratio of biopolymer types and concentrations,

temperature, pH, and ionic strength. Through these controls, charged species (such as H^+ and OH^-) present on the surfaces of biopolymers interact via electrostatic complexation, ultimately resulting in the development of 3D networks and gel formation[37,40]. Pandey *et al.*, conducted a study where they developed a mixed emulsion gel for the delivery of *Lactobacillus plantarum* 299v. The researchers investigated how strong the gel was and how quickly it fell apart. They noticed that by adding both xanthan gum and guar gum to the mix, the gel became a lot stronger and could withstand stomach acid better.

Furthermore, the emulsion gel based on natural gums, when stored under different conditions including 4°C, -20°C, also -190°C, exhibited increased survival rates of the capsules containing probiotics compared to control group. This suggests that the emulsified gel made of natural gums provided better protection and preservation for the encapsulated probiotics during storage[47]. Hou *et al.*, conducted a study where they developed emulsion gels that incorporate a blend of components and are created through the enzymatic (mTGase) gelation process. These gels were composed of flavored corn oil and were held stable by combinations created from soy protein isolate and sugar beet pectin. The researchers observed that the complex, emulsified gel formulations displayed denser structures in contrast to other variations. This compact structure was attributed to an effective interfacial network creation, which resulted from a higher absorption of emulsifiers at the interfaces between oil and water phases. Gas chromatography analysis conducted, and the outcomes revealed that the release rate of ethyl butyrate (a flavor compound) was significantly lower in the emulsion gels both before and after the mastication process. The reduced rate of release was linked to the tightly packed structure of the emulsion gels[48]. Zou *et al.*, conducted a study where they created Pickering emulsion gels by using a 50% volume fraction of corn oil. These emulsion gels were made stable by incorporating complex Pickering particles composed of zein and tannic acid at concentrations ranging from 1% to 1.5% by weight. These complex Pickering particles displayed a three-phase contact angle of about 86°, indicating their strong interfacial effectiveness. The resulting emulsion gels, formed with these complex Pickering particles, exhibited a uniform structure and maintained excellent stability over a 30-day storage period. There were no indications of issues such as oil separation, creaming, or phase separation. This stability was attributed to the transformation of the emulsion gels transitioning from a liquid state to a partially solid state as a result of the formation of particle networks[49] which are formed via modulation of the noncovalent interactions between macromolecules and natural small molecules, can be developed as novel functional ingredients in a safe and sustainable way. For this study was prepared a novel zein/tannic acid (TA. Wei *et al.*, carrid out research in which, reacted emulsion gels with high concentrations by employing intricate Pickering particles consisting of ovotransferrin also lysozyme as stabilizers. When the particle concentration was raised from 0.5% to 2% by weight, the size of the droplets in the emulsion gels reduced from 81.4μm to 42.4μm while maintaining a fixed oil phase concentration of 75%.

The emulsion gels formed with the complex Pickering particles demonstrated outstanding resilience over extended storage periods. They effectively prevented the separation of phases phenomena due to creating a network of particles, which were attributed to electrostatic interactions between the particles[50] as confirmed by turbidity titrations, was proved to be an effective means to prepare food-grade particles. Multiple parameters such as particle size, zeta potential and dispersion stability were characterized in screening for proper OVT–LYS particles as Pickering stabilizers. OVT– LYS particles with OVT/LYS ratio of 8:1 at pH 9.3 met all requirements of eligible Pickering stabilizers such as intermediate wettability. Titrations in the presence of sodium chloride demonstrated that primary driving force of OVT–LYS particle formation was electrostatic attraction. Afterwards, food-grade Pickering emulsions were fabricated using OVT–LYS particles. Visual observation indicated that Pickering emulsions stabilized by 33 OVT–LYS particles at various particle concentrations and oil fractions were stable during 34 one-month storage at room temperature, and OVT–LYS particles could stabilize high 35 internal phase Pickering emulsions at oil fraction of 0.75. Rheological measurements revealed that viscosity and gel-like structures of Pickering emulsions were dependent on particle concentration and oil fraction. When compared with the extent of lipolysis (32.1%. The use of Pickering particles to stabilize emulsion

gels resulted in an enhanced availability of embedded curcumin by 22.2%. This finding suggests that emulsion gels function as a reliable method for transporting bioactive substances that are soluble in fats[51].

3. Materials and Methods

3.1 Selection of Oil Phase

Emulgels are essentially emulsions that have transformed into a gel due to the inclusion of a gelling agent. The choice between o/w or w/o emulsions is dictated by the intended purpose. The intended use of the product is the main determinant of the composition and proportion of the oil phase in the emulsion. Unless it acts as an active ingredient by itself, the oil component in pharmaceutical and cosmetic goods normally consists of different lipids of either natural or synthetic origin. This lipid can exhibit a wide range of consistencies, ranging from fluid liquids to solid fats. Different oils used in emulgels formulations vary in their applications, properties, and utility. Optimization of any formulation should consider the specific type of oil to be utilized, taking into account its significance and utility[52]. Schematic diagram for the preparation of polysaccharide-based emulgels by ionic cross-linking is shown in Figure 2[53]. Extensive research has been conducted to study how the oil component affects different factors like thickness, the ability to pass through, and the endurance of the emulsion. Medicinal properties can be found in oils extracted from different plant sources, presenting an opportunity to harness these beneficial components and invent a potent solution utilizing a recently innovated delivery method known as "Emulgel". A specific oil with significant medical relevance is Geranium oil. Geranium oil has been traditionally used to control bleeding, promote wound healing, treat skin conditions and ulcers, and also alleviate symptoms of colic, dysentery, and diarrhea. Furthermore, the oil has antibacterial and insecticidal qualities[54,55].

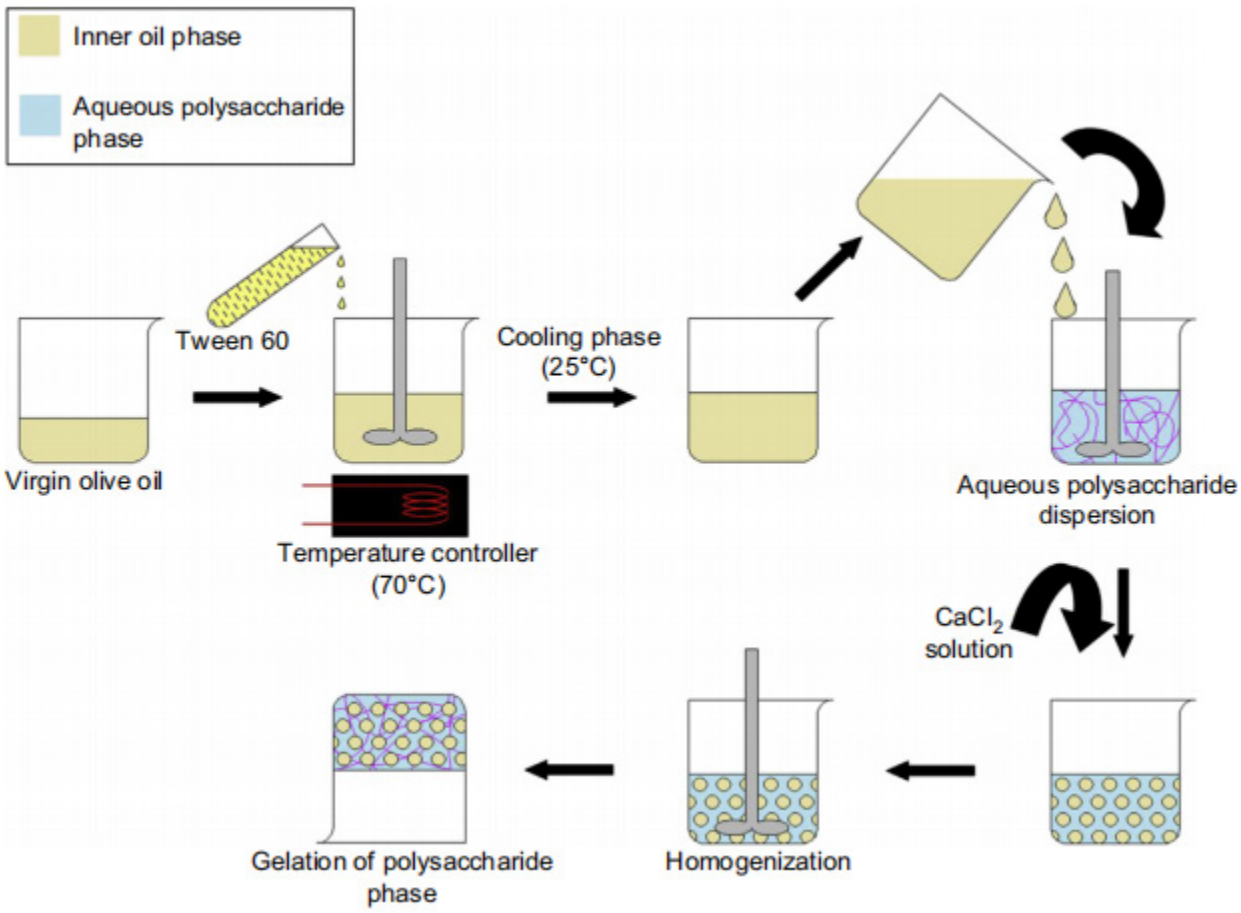

Figure 2. Schematic diagram for the preparation of polysaccharide-based emulgels by ionic cross-linking[53].

Likewise, Research has shown that garlic has impressive qualities that can help speed up the healing process of burn injuries[56]. Additionally, there are various other medicinal plants, including *Arnelia nobilis*, *Garciana indica*, *Boehavia diffusa*, *Solanum albicaule, Vitex nigundu*, *Buniun persicum*, *Acacia concinna*, and *Albizia lebbec*, which also possess healing properties for various purposes. These plants can be utilized for their therapeutic benefits, were subjected to investigation regarding their antimicrobial efficacy. Analysis of ethanolic extracts from these plants revealed encouraging antimicrobial properties against certain bacteria and fungus[57]. Nutrient quercetin, known for its potent antioxidant properties, can be obtained in diverse formulations such as gels and creams. Nevertheless, its ability to effectively penetrate the skin is notably enhanced when formulated as a microemulsion. Besides Quercetin, several herbal drugs have been converted into emulsions to optimize their characteristics. These include Zedoary oil, Brucea Javanica oil, Coixenolide oil, and Camtothecin[58,59]. In an independent study conducted by Shahin *et al.*, in 2011, researchers carried out experiments where they used jojoba oil as a key component in creating an emulgel formulation. More specifically, they formulated an Emulgel that had clotrimazole as an ingredient and incorporated jojoba oil as a crucial part of the oily phase. The choice of jojoba oil for the oil phase was made because of its potential to reduce inflammation, which is frequently associated with fungus infections. The study also shown its efficacy in reducing inflammation in a variety of animal models used in experimentation[60]. Perioli *et al.*, conducted research in 2008 to develop an emulgel formulation suitable for buccal administration. The formulation used Compritol®888ATO, a neutral lipid glycerol behenate, as the oil phase. Sustained-release tablets and capsules, among other medicinal dose forms, frequently use the excipient Compritol®888ATO. The research conducted by Perioli, and their team showed that the formulations that worked the best had a moderate amount of oil, not too much or too little. Specifically, the weight ratio of oil to water ranged from 0.3 to 0.4, which was found to be the most effective. These preparation exhibited suitable viscosity levels, making them compatible with administration via pre-filled syringes[61] intended for the buccal administration of the antiinflammatory drug flurbiprofen. The influence of formulation parameters, such as (a. Mineral oils, specifically liquid paraffin, have been utilized as the oil phase in numerous Emulgel formulations[60-65]. Paraffin wax, which is a type of oil that can turn into crystals, is used in many different ways. One important use is as something called a "phase change material" or PCM. Paraffin wax has some great qualities for this job. It can hold a lot of heat, doesn't easily turn into a gas, and doesn't react with other chemicals. When you mix paraffin wax with water, you get something called a paraffin/water mix. This mix is really helpful for lots of things because it's really good at moving heat around and doesn't slow down heat transfer much[66]. In one study by Caifu Li in 2010, they looked at tiny drops of paraffin wax mixed in water and found that these drops were solid and irregularly shaped, which made the mixture more stable. Another study by Shishu and others in 2009 created a special mixture with Acyclovir for treating skin herpes. They used certain oils in their formula, and the best version had an ingredient called Transcutol that helped the medicine go through the skin better, making it work 1.7 times faster than regular creams. Oleic acid, a type of oil, can also be used in these mixtures. It's a clear oil that can sometimes have a slight yellow color. It's found in many fats like olive oil and peanut oil, and it's useful in making these mixtures[67] Total Phenolics (TP). A special mixture was created to deliver terbinafine through the skin over 24 hours. They used a type of oil called oleic acid, and they figured out the right amounts of oil, emulsifier, co-emulsifier, and water by making charts when they tested this mixture against *Candida albicans* and *Aspergillus flavus*, the fungus that causes infections, it worked better than the product you can buy in the store[68].

3.2 Selection of Emulsifiers

Emulgels that consist of o/w or w/o, and they can be transformed into a gel-like consistency by incorporating gelling agent. Emulsions, being thermodynamically wobbling systems, require the use of suitable emulsifying agents to reduce interfacial tension and enhance their stability. An effective emulsifier should possess a well-balanced combination of hydrophilic and lipophilic groups, enabling the production of stable emulsions[69]. The choice of an appropriate emulsifying agent and determining its optimal concentration

are based on practical knowledge and a process of experimentation[70,71]. Nonionic surfactants like spans and tweens possess HLB values exceeding 8, making them suitable for formulating o/w emulsions. Conversely, mineral oils such as liquid paraffin have HLB values below 8, which makes them suitable for formulating w/o emulsions. An emulgel was formulated by incorporating tween 20 as an emulsifier in the aqueous phase and span 20 in the oily phase[70-73]. Both spans and tweens, which are types of surfactants, are sorbitan lauric acid esters and have a similar cyclic structure. However, Tween 20 stands out because it contains extra polyoxyethylene units[74,75]. Tweens are made up of polysorbate molecules, each containing a hydrophilic head group consisting of chains of Oligo (Ethylene Glycol) (OEG), along with a hydrophobic tail made of a fatty acid ester part[76,77].

The combination of Span 20 and Tween 20 in emulsions contributes to enhanced stability compared to using either pure Tween or Span systems alone[78]. The polymeric emulsifier known as Pemulen was used as the emulsifier in creating an emulgel intended for buccal administration. Pemulens are acrylic acid copolymers that have been modified with Acrylates/C10–C30 alkyl acrylates to make them hydrophobic. These polymers act as both the main emulsifiers for oil-in-water (o/w) emulsions and as agents that enhance viscosity. They work by stabilizing o/w emulsions, where their short lipophilic part integrates into the oil droplets, while their long hydrophilic part forms a micro-gel around the droplets[79]. An emulgel was developed to treat mycetoma caused by *Actinomadurae madura*. The formulation involved creating an oil-in-water (o/w) emulsion by mixing the oily phase (liquid Vaseline, span 60, and erythromycin ethylsuccinate) with the aqueous phase (Tween 60, water, and kanamycin sulphate) at 70 °C. Different characteristics of the emulsion, such as the amount of surfactant (5% and 10%) and the Hydrophilic-Lipophilic Balance (HLB) values (9.01 and 10), were adjusted to find the most stable formulation using a centrifuge test. The emulsion with 10% surfactant and an HLB value of 10 was chosen as the best formulation for preparing the emulgel[80]. Surfactants, commonly used in various applications, are known to possess toxic properties that can pose risks to both health and the environment. To address these concerns, biosurfactants have emerged as a viable alternative. Biosurfactants are produced by microbes and can be specific to certain genera or even species. They have a unique structure with short fatty acid tails and hydrophilic head groups, making them both hydrophilic and hydrophobic. Similar to chemical surfactants, biosurfactants effectively reduce surface and interfacial tension. What sets biosurfactants apart and makes them a promising alternative to chemically synthesized surfactants are several key features. Firstly, biosurfactants exhibit lower toxicity, making them safer for human health and the environment. Additionally, they possess higher biodegradability, ensuring greater compatibility with the environment. Moreover, biosurfactants demonstrate stable activity under high pH and temperature conditions. These characteristics make them commercially attractive due to their improved foaming properties and their potential to serve as effective emulsifiers in dispersed systems, such as emulsions.

Therefore, biosurfactants offer a superior option for those seeking emulsifying agents, as they provide the advantages of reduced toxicity, enhanced biodegradability, improved foaming properties, and stability across a wide range of pH and temperature conditions.

3.3 Selection of Gelling Agent

The inclusion of a gelling agent in these formulations results in the formation of a gel-like structure. Gelling agents can be classified into two categories: natural and synthetic. The introduction of a gelling agent to a system induces thixotropic behavior[81]. As per the Swedish National Encyclopedia (1989-1996), thixotropy refers to the characteristic of a viscous or gel-like substance that becomes more fluid over time and with increased agitation, such as through stirring[82]. Thixotropy is widely recognized as the occurrence of reversible structural transitions in a fluid, resulting in a conversion between a gel-like state and a more liquid state. This transition is influenced by factors such as temperature, pH, or other components, leading to time-dependent changes in viscosity without altering the overall volume of the system[83]. The way a system changes from a gel to a liquid and back again is really important for keeping it stable and making sure substances can be used effectively. But lots of things can affect how stable the system is, like how acidic

it is, how hot it is, how much polymer is in it, and if different polymers are mixed together. Hydroxypropyl methylcellulose, which is made from a natural material called cellulose but is changed to be synthetic, is a white or slightly off-white powder that doesn't smell or taste like anything. It can come in small fibers or granules, and it flows easily[84]. Hydroxypropyl methylcellulose is used as a thickener, tablet binder, for making modified release formulations, and as a material for coating films. On the other hand, Carbopol polymers are made of acrylic acid and are cross-linked with polyalkenyl ethers or divinyl glycol. These polymers are made from small primary particles with an average diameter between 0.2 and 6.0 µm. Each particle can be seen as a network structure made of interconnected polymer chains, held together by cross-linking[85] Tween 80, sodium dodecylsulfate (SDS. Carbomers possess the ability to readily absorb water, undergo hydration, and swell. Carbomers are great for controlled-release drug systems because they can soak up water easily, swell, and get hydrated. They're perfect for this because they love water, have a structure that's cross-linked, and don't dissolve in water. Recently, people made an insect repellent cream using carbopol as a key ingredient. They noticed that the cream's texture changed a lot based on how good the carbopol was and how much they used, along with other stuff in the mix.

Researchers also studied how adding a gelling agent affects how fast a drug is released from an emulgel. They found that as the concentration of the gelling agent increased, less drug was released. The emulgel they made acted like a non-Newtonian fluid, getting thinner when pushed but not thickening back up afterward. The thickness of the emulgel changed depending on how much and what type of gelling agent they used. Stability tests showed that mixtures with a small amount of Carbopol or a mix of two gelling agents were more stable under different conditions, like spinning them around, changing the temperature, or storing them for a year, compared to other formulations[25]. In comparison to Carbopol-based emulgel, emulgel formulated with HPMC (hydroxypropyl methylcellulose) demonstrated an improved drug release rate. This indicates that the HPMC-based emulgel exhibited superior performance in terms of delivering the drug[86]. Pemulen, a type of polymeric emulsifier, exhibits both mucoadhesive and emulsifying properties, as mentioned earlier. When the aqueous dispersion of the polymer is neutralized with NaOH, the polymer chains undergo expansion, resulting in the formation of a clear and stable gel. To achieve complete hydration of the polymer, it is necessary to store the gels at 4°C for 24 hours prior to the addition of the oil phase.

Pemulen was used as a gelling agent in creating an emulgel meant for buccal administration. Studies on the rheological and pharmaceutical properties of these emulgels, formulated with the mucoadhesive polymer Pemulen, have shown that they stay in place longer than current products on the market for treating oral cavity inflammations. Adding the polymeric acrylic emulsifier to the emulgel formulation helps maintain its texture, stability, and ability to stick to mucous membranes[87] intended for the buccal administration of the antiinflammatory drug flurbiprofen. The influence of formulation parameters, such as (a. The recently identified property is valuable for formulations needing extended retention, possibly reducing the need for frequent applications. For example, a vaginal emulgel was created with benzydamine as its active ingredient[88]. A total of nine formulations were prepared by varying the types and concentrations of gelling agents. The gelling agents used were hydroxyethyl cellulose (HEC) and sodium carboxymethyl cellulose (NaCMC). The most effective emulgels for vaginal use typically contain NaCMC at a 3% concentration, displaying superior performance both in laboratory tests and in real-life scenarios. These formulations exhibit better adhesion to mucous membranes and longer-lasting effects compared to the popular product Tantum Rosa. Although HEC-based Emulgels have good drug release properties and acceptable rheological characteristics, their ability to stick to mucous membranes is lower. Alongside HEC and NaCMC, various synthetic and semisynthetic gelling agents are available for use. However, natural gelling agents are vulnerable to microbial decay, prompting a shift towards synthetic options. Sodium carboxymethyl cellulose, a cellulose derivative, is widely chosen as a gelling agent, especially for creating sterile jellies, as it can withstand Steam heat sterilization without significant damage.

In another investigation, researchers developed a topical gel with colocynth extract known for its anti-inflammatory effects, utilizing sodium carboxymethyl cellulose as the gelling agent at a 5% concentration.

They compared the anti-inflammatory efficacy of this gel with Volteran Emulgel. Schematic diagram for the preparation of emulgels using synthetic hydrophilic polymers is shown in Figure 3[53].

4. Advantages

- Emulgels are becoming more important in pharmaceutical and food sectors due to their numerous benefits. A key advantage is their capacity to include hydrophobic drugs within the emulsion's oil phase, effectively addressing the challenge of low solubility. Combining the emulsion with the gel base helps overcome this issue, facilitating the delivery and skin penetration of these drugs[89,90].
- The advantages of emulgels in drug release compared to conventional topical formulations like ointments, creams, lotions, and pastes. While these formulations often contain oil excipients hindering drug release, gel-based emulgels allow for the inclusion of water and the aqueous phase, resulting in less viscous and greasy preparations. Consequently, emulsion-based gels prove highly suitable for the release and delivery of hydrophobic active substances, encompassing drugs, cosmetics, and food ingredients[91].
- Emulgels provide controlled release and targeted drug delivery through dual controlled release mechanisms involving both emulsion and gel systems. This enables the regulation of drug release from the formulation, leading to extended drug effects and longer therapeutic benefits[92].
- Emulgels offer several advantages over traditional ointments and creams. They have excellent spreadability, a non-greasy texture, and exhibit thixotropic properties, making them more pleasant to use. Unlike ointments and creams, which can be sticky and require rubbing during application, emulgels are easy to apply and can be easily removed while still providing moisturizing benefits, thereby improving patient compliance[93,94].
- When prepared accurately, emulgels usually demonstrate outstanding physical stability due to the inclusion of effective emulsifiers, leading to reduced interfacial tension. This increased stability results in a prolonged shelf life compared to alternative transdermal formulations such as creams and ointments. Creams frequently encounter phase inversion or separation, whereas ointments can develop rancidity due to their oily composition. Conversely, emulgels provide improved stability, making them a preferred option for formulation longevity[95,96].
- Emulgels have advantages over certain novel drug delivery systems like niosomes and liposomes, particularly in terms of loading capacity. While vesicular systems like niosomes and liposomes may encounter problems like leakage and lower entrapment

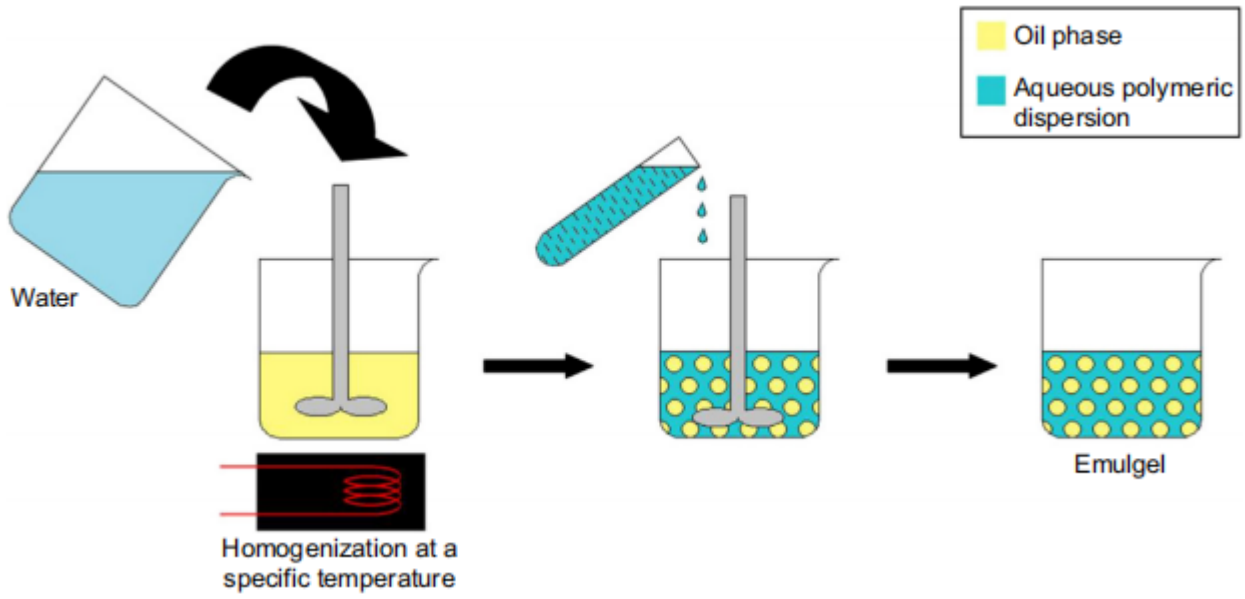

Figure 3. Schematic diagram for the preparation of emulgels using synthetic hydrophilic polymers[53].

efficiency, emulgels offer a network structure that enables better loading capacity and entrapment of active substances. Unlike the preparation of vesicular drug delivery systems, which often requires intensive sonication leading to potential drug degradation and leakage, emulgel production does not necessitate sonication, addressing this issue[97].

- Another key benefit of emulgels is their ease of production and cost-effectiveness. The manufacturing process for emulgels is uncomplicated and requires only simple and brief processing steps, eliminating the necessity for expensive specialized equipment. Additionally, the materials needed to prepare emulgels are usually easily obtainable and affordable[21].
- The usage of emulgels provides numerous advantages, particularly in the field of pharmacy. The demand for emulgels is steadily increasing over time due to their various benefits.
- Emulgels offer a solution to avoid the potential drawbacks associated with intravenous treatments. Emulgels assist in addressing issues associated with diverse adsorption conditions, including digestive transit, enzyme presence, and pH fluctuations.

5. Disadavantages

Emulgels offer numerous advantages, yet they also come with certain drawbacks. One notable disadvantage involves the possible entrapment of bubbles during their preparation. Additionally, it's crucial to acknowledge the potential for skin irritation in individuals with contact dermatitis and the risk of triggering allergic reactions (source). Nonetheless, this concern can be mitigated by subjecting the gel to sonication for approximately 15 minutes[98].

- Topical drug delivery systems often face a hurdle in drug permeability through the skin, mainly because of its dense and intricate structure. This makes it challenging for large drug particles to be effectively absorbed. However, one way to tackle this issue is by including penetration enhancers in the emulsion gel[99].
- Nevertheless, emulgels also come with certain disadvantages that can limit their effectiveness in delivering hydrophobic drugs.
- To address this limitation, emulgels are being utilized extensively nowadays. By using emulgels, the disadvantage of delivering hydrophobic drugs is effectively overcome. This allows hydrophobic drugs to leverage the distinctive properties of gels for improved delivery.
- There are several major disadvantages associated with emulgels. These include the large particle size of the drug, which hinders its ability to pass through the skin effectively. The permeability of emulgels can also be poor, limiting the absorption of the drug. Additionally, there is a risk of skin allergies or contact dermatitis occurring as a result of emulgel application. In some cases, the application of emulgel may also lead to the formation of bubbles.

6. Building Block of Nanoemulgel

Nanoemulgels are typically comprised of various elements, including a base, emulsifiers, gelling agents, and substances that boost permeation[22]. The medium within a nanoemulgel, termed as the vehicle, encompasses either an aqueous or oily base wherein the formulation's constituents are dissolved or dispersed. For externally applied emulsions, mineral oils are frequently employed either individually or in conjunction with hard or soft paraffin as a carrier for delivering drugs. This preference is due to their occlusive characteristics, which assist in averting transepidermal water loss (TEWL) from the skin[100].

In the case of internally applied emulsions or oral dosage forms, a variety of fixed oils are often utilized, including castor oil, corn oil, cottonseed oil, peanut oil, and fish liver oil. These oils have a dual role, serving not only as carriers for drug delivery but also as nutritional supplements[101]. Balsam oil, castor oil, birch oil, wheat germ oil, rosehip oil, and myrrh oil are among the commonly used oil phases in nanoemulgels[22].

6.1 Emulsifiers

Emulsifying agents are surface-active substances that are added to emulsions to improve their stability by functioning at the boundary between the two phases. They boost the dynamic stability of the emulsion, thwarting notable alterations in droplet dimensions over time[102] energy, and environmental industries such as the food, health care, chemical synthesis,

and firefighting sectors. Water-in-oil emulsions are formed spontaneously during oil production when oil and water are mixed together and in the presence of asphaltene as a naturally occurring surfactant. For operational and economic reasons, oil emulsions need to be treated to recover both oil and water phases. To develop more efficient emulsion treatments, it is essential to have a better understanding of the factors that affect emulsion formation and stability. The droplet size variation is an important parameter that influences the stability and rheological characteristics of the emulsions. In addition, the available interfacial area for any possible chemical reactions might affect the behaviours and properties of the emulsions in various transport phenomena systems. The adequate knowledge of the factors and mechanisms affecting the droplet size and emulsion stability still needs further engineering and research activities. This study is aimed to provide a comprehensive literature review on the formation of water/oil emulsions and their stability in various physical systems (e.g., pipeline networks and porous media. Emulsifiers are compounds typically characterized by both a hydrophilic (water-soluble) and a hydrophobic (oil-soluble) segment. This property enables emulsifiers to exhibit favorable solubility in either water or oil. According to the Bancroft rule, the phase in which an emulsifier demonstrates greater solubility will constitute the continuous phase of the emulsion. Proteins, with their greater solubility in water compared to oil, serve as emulsifying agents that facilitate the creation of oil-in-water (o/w) emulsions[103]. Conversely, sorbitan fatty acid esters, nonionic surfactants that are oil-soluble, aid in the development of water-in-oil (w/o) emulsions. On the other hand, water-soluble surfactants such as polyoxyethylene sorbitan fatty acid esters (tweens) encourage the formation of oil-in-water (o/w) emulsions[104]. The selection of an emulsifying agent for a formulation can be influenced by the targeted Hydrophilic-Lipophilic Balance (HLB) value, which is reliant on the HLB value of the oil phase being used[105].

6.2 Gelling Agents

Gelling agents play a crucial role in nanoemulgel formulations by ensuring the desired texture is maintained. Some gelling agents dissolve in the liquid phase, creating a colloidal mixture that leads to the formation of a loosely interconnected internal structure through cross-polymerization. Meanwhile, other gelling agents demonstrate a thixotropic effect, meaning they exhibit time-dependent shear thinning properties, where discrete particles adhere or interlock to resist strain[106] inflammatory, systemic autoimmune disease, affecting the joints with varying severity among patients. The risk factors include age, gender, genetics, and environmental exposure (cigarette smoking, air pollutants, and occupational. In the formulation of nanogels and nanoemulgels, permeation enhancers, also known as sorption promoters or accelerants, are used alongside gelling agents. These substances function by decreasing the skin's barrier resistance in a reversible manner.

Skin penetration enhancers operate through various mechanisms, such as:

- Disruption of the intercellular lipid matrix,
- Disruption of the intracellular keratin domain, and
- Increasing the partitioning of the drug into the tissue by acting as a solvent for the permeating substance within the membrane[107].

Examples of penetration enhancers encompass sulfoxides like dimethyl sulfoxide, azones such as laurocapram, pyrrolidones like 2-pyrrolidone (2P), alcohols like ethanol and decanol, glycols including propylene glycol (commonly used in topical formulations), surfactants, and terpenes. Gelling agents play a pivotal role in determining numerous characteristics of nanoemulgels, including their physical uniformity, texture, bio-adhesive properties, swelling behavior, rheological attributes, drug release profiles, ease of extrusion, and spreadability.

These substances can be categorized into natural, semisynthetic, and synthetic classes based on their origins, as elaborated in the subsequent section.

6.2.1 Natural Polymers

Natural polymers, including bio-polysaccharides such as pectin, gelatin, carrageenan, locust bean gum, alginic acid and its derivatives, starch, succinoglucon, dextran, xanthan gum, gum acacia, gum tragacanth, and guar gum, along with proteins like collagen,

casein, and egg whites, serve as gelling agents derived from natural sources. Some of these gelling agents are extracted from plants. For example, Pinus Koraiensis Polysaccharide (PKP), categorized as a plant heteropolysaccharide, has been investigated as a gelling agent to enhance the therapeutic effectiveness of paclitaxel in cancer chemotherapy. The paclitaxel-loaded gel demonstrated favorable injectable properties, quick recovery time, thixotropic behavior, desirable rheological characteristics, and notable antitumor activity against 4T1 and MCF-7 breast cancer cell lines, while also reducing toxicity *in vivo*[108]. Upadhyay *et al.*, conducted a study aiming to formulate a nanoemulgel based on guar gum, intended for enhanced bioavailability and effective topical delivery of Finasteride to address androgenic alopecia. The researchers utilized a high-energy emulsification technique to create the nanoemulsion, incorporating cholesterol, soy lecithin, and vitamin E in the lipid phase, while guar gum served as the gelling agent. The pH of the nanoemulgel formulation was found to be 5.37 ± 0.74, indicating compatibility with the skin. The system demonstrated a gradual release of the drug, with permeation restricted to 94.77% and 30.7% within 24 hours. The particle size of the nanoemulgel was measured at 195.20 nm, exhibiting a negative zeta potential of -7.61 mV[109].

6.2.2 Semisynthetic Polymers

Hydrophilic gelling agents, such as cellulose derivatives like hydroxypropyl cellulose, hydroxyethylcellulose, carboxymethyl cellulose, sodium alginate, and magnesium aluminum silicate, possess water-binding properties owing to functional groups like -NH_2, -COOH, -SO_3H, and -OH. They offer high water capacity, stability, and responsiveness to environmental factors, making them biocompatible and suitable for various biomedical applications. Setya *et al.*, developed a transdermal nanoemulgel system for Tacrine hydrochloride, utilizing a low-energy emulsification method with ethyl cellulose as the gelling agent, resulting in improved drug absorption, enhanced neurobehavioral parameters, and long-term stability demonstrated in *in vivo* studies on male Wistar rats[110]. El-Salamouni *et al.*, carried out research to create a methyl cellulose-based nanoemulgel to treat inflammatory skin conditions such atopic dermatitis. A natural medication consisting of a 1:1 ratio of chamomile oil to olive oil was included in the formulation. 10% w/w propylene glycol and a mixture of surfactants and cosurfactants (Smix), such as tween 20/80 or Gelucire 44/14, were used for emulsification. The gelling ingredient used was 3% w/w methylcellulose dissolved in water. The nanoemulgel had a pH of 5.56 that was suitable for human skin, a negative zeta potential, and a particle size of less than 200 nm. When compared to the usage of chamomile oil alone, it showed improved skin healing capability, outstanding physical stability, and spreadability[111].

6.2.3 Synthetic Gelling Agents

Carbomers, poloxamers, and polyvinyl alcohol are synthetic gelling agents that have been approved by the FDA. Carbomers, which are commonly known by the brand name Carbopol, are polymers formed through the polymerization of acrylic acid. They have a high capacity to swell in water due to the dissociation of positively charged sodium ions when in dry powder form. Typically, carbomers exhibit thickening properties at pH levels around 5-6. Different grades of carbomers, such as carbopol 910, 934, 934p, 940, and 941, are available, with variations in molecular weight and molecular components. Carbopol 910 and 941 are low viscosity grades, ranging from 3000 to 10,000 centipoises, making them suitable for low consistency gels with high clarity. On the other hand, carbopol 934, 934P, and 940 are high viscosity grades (30,00050,000 centipoises) and are effective in thick formulations. They can form clear gels when combined with water or hydroalcoholic frameworks, commonly utilized in topical or transdermal formulations[112]. Poloxamers, alternatively recognized as Pluronics, Kolliphor, or Synperonics, are copolymer systems featuring a nonionic triblock configuration. They undergo a phase transition from liquid to gel when subjected to temperature variations, leading to the formation of micellar structures. Renowned for their safety and versatility, they serve as emulsifiers, stabilizers, and play crucial roles in drug delivery

systems designed for oral, topical, and parenteral administration[113].

7. Rational of Emulgels as New Formulation

Dermatological formulations, such as ointments and creams, come with significant drawbacks. These challenges encompass limited spreadability, penetration, and reduced patient adherence due to the adhesive nature or the need for rubbing during application. Additionally, gels encounter difficulties in efficiently delivering hydrophobic medications. In the past, ointments, creams, and lotions were commonly utilized for treating various infections. However, due to several factors and limitations associated with these preparations, emulgels have gained recognition in both cosmetics and pharmaceutical applications[101]. Therefore, emulgels offer a solution to the problem of drug solubility and improve drug penetration.

The use of emulgels in drug delivery offers advantages such as enhanced penetration of the drug into soft tissues, resulting in a reduced required dosage for therapeutic effect and increased pharmacological action. Furthermore, the inclusion of specific excipients can contribute to the overall pharmacological activity of the emulgel. In contrast, conventional topical dosage forms like moisturizers, creams, and ointments suffer from various drawbacks[114].

One of the limitations of traditional topical formulations like moisturizers, creams, and ointments is their tendency to feel sticky and greasy, which can result in challenges for patients during application[115]. Moreover, the stickiness and greasiness of conventional topical dosage forms can also result in stability issues, particularly for hydrophilic drug formulations. These limitations associated with semi-solid preparations have led to the increased utilization of gel formulations in both pharmaceutical and cosmetic applications. However, despite the advantages offered by emulgels, there remains a significant challenge in effectively delivering drugs with hydrophobic properties[116].

8. List of Some Recently Explored Polymers used in Emulgel Formulations Along with the Associated Drug

Some of the recently explored polymers used in emulgel formulations are given in Table 2.

Table 2. Polymers used for emulgel formulations

Polymer	Drug	Reference
Polyvinyl Alcohol	Diclofenac Sodium	99
Eudragit	Ketoprofen	
Chitosan	Miconazole Nitrate	
Poloxamer 407	Diclofenac Diethylamine	
Polyethylene Glycol	Ibuprofen	
Polycaprolactone	Flurbiprofen	

9. Challenges

9.1 Stability Issue

Emulgels often face issues like separating into different layers, forming cream-like structures, or combining them into larger droplets as time goes on, which can ultimately make the product less stable. Guaranteeing that the emulgel remains stable over an extended period is a major challenge[117].

9.2 Selection of Appropriate Emulsifier

Selecting the appropriate emulsifier or a combination of emulsifiers is essential for creating stable emulsions within emulgels. the choice of emulsifiers relies on how well they blend with both the oil and water components and aligns with the intended use of the emulgel[118].

9.3 Active Ingredient Compatibility

Ensuring that the active ingredient in pharmaceuticals (known as the API) remains effective and doesn't degrade within the emulgel formulation can pose difficulties, particularly when dealing with delicate or easily degradable drugs[119].

9.4 Preservative Selection

Selecting suitable preservatives to hinder the growth of microorganisms, all while making sure they don't interfere with the other components of the formulation, can be quite a complex task[120].

9.5 Rheological Properties

Achieving the right texture, spreadability, and ease of application in emulgels by fine-tuning their rheological properties can be a complex task[121].

9.6 Regulatory Compliance

In the pharmaceutical sector, complying with regulatory standards and maintaining quality control throughout the formulation development and manufacturing processes can pose significant difficulties[122].

9.7 Scalability

Moving from small-scale laboratory formulations to large-scale commercial production while ensuring that the product maintains uniform quality and stability can be quite a demanding task[123].

10. Current and Future Perspectives of Nano-emulgel

The process of creating nanoemulgels involves carefully selecting ingredients like surfactants, co-surfactants, oils, and gelling agents, each with its distinct characteristics. The choice of manufacturing method also influences the final product. The key to achieving a stable nanoemulsion and transforming it into a nanoemulgel lies in selecting the right components and manufacturing approach. Compared to traditional nanoemulsions, hydrogel-thickened nanoemulgels are more efficient for transdermal drug delivery. This thick formula offers improved stability, enhances drug delivery, and is particularly effective for lipophilic drugs. It stays on the skin longer, forms a thin layer, and keeps the skin hydrated. The availability of nanoemulgel formulations in the market indicates potential therapeutic benefits and growing research interest. Incorporating nanoemulsions into hydrogels has shown promise in various medical conditions, demonstrating significant progress in pharmaceutical formulation science. These formulations are appealing due to their non-greasy, gel-like sustained release properties.

Nanoemulgels have the potential to deliver active ingredients effectively for treating various infections and conditions, but more research on drug absorption is needed. This innovative transdermal dosage form holds promise for targeting specific skin issues and improving the treatment of systemic ailments.

Dealing with hydrophobic drugs in formulation development has been challenging due to their low solubility and poor bioavailability. Creams, ointments, and lotions are common topical solutions but suffer from slow drug release due to their oily bases. In contrast, aqueous gels offer a more favorable setting for drug release. To tackle this issue, hydrophobic medications are blended with oily bases to form emulgels, which are then nano sized into nanoemulgels with enhanced characteristics. Continued research in nanoemulgels offers hope for revitalizing drugs with bioavailability and efficacy issues. While commercializing nanoemulsion production is currently challenging, evolving technologies may make it feasible in the future. Given the advantages of nanoemulgels over other formulations, an increase in their production is expected.

10.1 Current Perspectives

- Dermatology and Skincare: Emulgels are often used in dermatology for their ability to deliver active ingredients deep into the skin, providing benefits such as hydration, anti-aging effects, and treatment of skin conditions like acne or eczema.
- Topical Drug Delivery: Emulgels have gained attention in the pharmaceutical industry as carriers for topical drug delivery. They can enhance the solubility and permeability of drugs, leading to improved therapeutic efficacy.
- Cosmetics: Emulgels are popular in the cosmetic industry due to their smooth texture and ease of application. Emulgels are employed in a range of cosmetic products such as creams, lotions, and sunscreens. They contribute to stability by preventing phase separation and ensuring a uniform mixture of oil and water-based ingredients, which can potentially prolong the shelf life of these products.

10.2 Future Perspectives

- Advanced Drug Delivery: Research is likely to focus on developing emulgels that can efficiently deliver a wider range of drugs, including those with poor solubility, to target sites within the body. This could lead to more effective treatments for various medical conditions.
- Nanotechnology Integration: The integration of nanotechnology with emulgels could enable

the encapsulation of nanoparticles containing drugs or other bioactive compounds. This could enhance targeted delivery and controlled release of therapeutic agents.

- Personalized Skincare: With advancements in skin analysis and diagnostics, emulgels might be tailored to individual skin types and conditions. Personalized formulations could provide optimized skincare solutions.
- Sustainability and Natural Ingredients: The trend toward eco-friendly and natural products might influence the development of emulgels that use sustainable ingredients and have minimal environmental impact.
- Incorporation of Active Ingredients: Emulgels could incorporate advanced active ingredients, such as peptides, growth factors, and stem cell extracts, to address specific skin concerns and promote skin health.
- Transdermal Drug Delivery: Emulgels could be engineered to facilitate transdermal drug delivery, allowing for controlled and sustained release of drugs through the skin, potentially replacing traditional oral or injectable routes for certain medications.

11. Conclusion

In this extensive review, we have journeyed through the realm of emulsion-based preparations, focusing on their classification, methods of selection, and the rationale behind Emulgels as a novel formulation. Emulgels, with their unique blend of properties and versatility, offer a promising avenue for addressing various challenges in pharmaceuticals, cosmetics, and beyond. This review has provided insights into the current state of Emulgels and their potential future applications, highlighting their significance in modern formulation science. Topical administration of medications will play a major role in improving patient compliance in the upcoming years. Emulgel is a relatively new topical drug delivery method that works well with hydrophobic medications. As it can also improve spreadibility, adhesion, and extrusion due to its iscosity. They will gain popularity as a medication delivery method. They will also be used as a loading solution for hydrophobic medications in a gel base that is soluble in water. As we conclude this exploration, it becomes evident that Emulgels represent an exciting frontier for research and innovation. Their adaptability, stability, and ease of formulation make them a valuable tool in the development of diverse products. With the ever-evolving landscape of science and technology, we anticipate that Emulgels will continue to play a pivotal role in shaping the future of materials and formulations. Researchers and industry professionals alike should remain vigilant, as new opportunities and applications in this field are bound to emerge. This review serves as a testament to the enduring relevance and promising outlook of emulsion-based preparations, reminding us of the endless possibilities they offer to enhance our lives and industries.

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