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Formulation and Evaluation of Mustard Oil Based Emulgel for Synergistic Enhancement in Topical Drug Delivery

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ABSTRACT

The development of emulgels as a novel topical drug delivery system has gained considerable attention due to their ability to combine the advantages of both emulsions and gels. This hybrid formulation enables the incorporation of both hydrophilic and lipophilic drugs, offering improved solubility, stability, and patient acceptability. Emulgels facilitate enhanced skin penetration and sustained drug release, making them particularly suitable for treating conditions such as inflammation, fungal infections, hormonal imbalances, and skin disorders. This review outlines the classification of emulgels into microemulgels, nanoemulgels, and macro-emulgels based on droplet size and stability. It also highlights essential formulation components like oils, surfactants, co-surfactants, gelling agents, and penetration enhancers. Moreover, the preparation method, evaluation techniques, therapeutic applications, and regulatory considerations are discussed in detail. With growing interest in nanotechnology and biopolymer-based systems, emulgels are poised to play a crucial role in future transdermal drug delivery approaches.

Keywords: Emulgel, topical drug delivery, nanoemulgel, microemulgel, controlled release, transdermal system, skin penetration, lipophilic drug delivery, formulation development, biocompatible polymers

1. INTRODUCTION

Delivering drugs through the skin isn't exactly new-but it has grown into one of the more efficient and patient-friendly ways to treat localized conditions. Instead of relying on pills or injections, topical delivery offers a more direct route, voiding the digestive tract and often minimizing the likelihood of widespread side effects. For people dealing with pain, inflammation, or skin infections, this route can be both simple and effective.

That said, not all topical formulations are created equal. Creams can be greasy, gels don't always hold onto oily drugs very well, and ointments, while potent, are often messy and uncomfortable. That's where emulgels come in a type of formulation that merges the structural strengths of emulsions and gels. By doing so, they provide a base that not only feels pleasant on the skin but also carries both water-soluble and fat-soluble drugs with relative ease.

What makes emulgels stand out is their dual-phase nature. The oil-in-water emulsion provides a medium for dissolving hydrophobic drugs, while the gel matrix lends viscosity, stability, and better application properties. For patients, this translates to a smoother application and longer-lasting effects. For pharmacists and formulation scientists, it offers a flexible platform to deliver different classes of drugs NSAIDs, antifungals, corticosteroids, and even cosmetics.

Lately, we've seen a surge in the exploration of nano-emulgels and micro-emulgels. These systems, built with much smaller droplet sizes, show even better skin penetration and controlled release profiles. And with better emulsifying agents and natural polymers entering the scene. emulgels are becoming more refined and sophisticated.

This review explores the growing promise of emulgels in pharmaceutical applications. We'll look at how they're made, what ingredients go into them, how they're evaluated, and perhaps most importantly how they're already being used in real-world treatments. As the industry pushes for more non-invasive, user-friendly drug delivery options, emulgels are quickly becoming part of that future.

2. Types of Emulgel

Not all emulgels are created the same. Depending on the type of emulsion that's embedded within the gel, these formulations can behave quite differently. In general, they fall into three main categories: microemulgels, nanoemulgels, and what we can simply call macro-emulgels. Each one has its own quirks when it comes to how stable it is, how well it delivers the drug, and how it feels when applied to the skin.

2.1 Microemulgels: Small Drops, Big Gains

Microemulgels are based on microemulsions those clear, almost magical systems where tiny oil droplets (typically 10 to 100 nano-meters) are dispersed in water Using surfactants and co-surfactants as aiding agents. Because of their small size and thermodynamic stability, microemulsions can load fat-soluble drugs really well and get them through the tough outer layers of the skin [21].

When a microemulsion is thickened with something like Carbopol or HPMC, you get a micro-emulgel. These are known for their smooth application, fast absorption, and long-lasting action. For example, one study found that a ketoconazole micro-emulgel worked more effectively against fungal infections than a standard cream [14].

2.2 Nanoemulgels: The Cutting Edge

Nanoemulgels are a bit newer to the scene and arguably more high-tech. They use nano-emulsions, which are similar to microemulsions but differ in that they are kinetically stable rather than thermodynamically stable. Their droplet sizes are typically under 200 nano-meters, and while they might not last forever, they stay stable long enough for clinical use if formulated correctly [25].

Smaller droplet sizes offer the advantage of improved skin penetration and more effective drug release. Studies have demonstrated that nanoemulgels can enhance the skin bioavailability of drugs such as ibuprofen and curcumin, which typically have difficulty penetrating the skin when used alone [24].

2.3 Macro-emulgels: The Classic Format

Macro-emulgels are kind of the "old school" version. Here, the emulsion has much larger droplets typically over 400 nano-meters which makes them a bit less stable than their smaller cousins. They may separate over time, especially if not stored properly, but they're still effective and easier to formulate.

Despite their simplicity, macro-emulgels are far from obsolete. They're still widely used for delivering drugs like clotrimazole and terbinafine for fungal skin infections. The bigger droplet size doesn't necessarily mean they work worse; it just means the formulation needs a bit more help staying together [2].

Quick Comparison Table: -

Type	Droplet size	Stability	Skin penetration	Example Drug
Micro-emulgel	10-100nm	Thermodynamically	High	ketoconazole
Nano-emulgel	< 200nm	Kinetically stable	Very high	Ibuprofen, Curcumin
Macro-emulgel	>400nm	Less Stable	Moderate	Clotrimazole, Terbinafine

3. Advantages and Disadvantages of Emulgel Systems

No drug delivery system is perfect but some come pretty close. Emulgels, in many ways, have managed to combine the best aspects of both gels and emulsions, making them a standout option in topical and transdermal drug delivery. From a formulator's perspective, the flexibility they offer is hard to beat. That said, they're not without their limitations, and understanding both sides of the equation is essential when deciding if an emulgel is the right vehicle for a particular drug.

3.1 Advantages: Why Emulgels Stand Out

Better for Lipophilic Drugs

Many of the drugs we want to apply to the skin don't dissolve well in water. Emulgels make it easier to incorporate these lipophilic compounds, since the emulsion's oil phase can handle them without breaking a sweat [23].

Spread ability and Comfort

Patients don't usually like greasy, heavy ointments. Emulgels are light, easy to spread, and generally absorb well into the skin. This makes thin more appealing for everyday use, especially in chronic conditions like arthritis or eczema [6].

Dual-Controlled Drug Release

Thanks to their structure, emulgels can slow down drug release. The drug has to get out of the emulsion droplets and then make its way through the gel matrix. This "two-step" process can help maintain therapeutic levels for longer periods [14].

Bypass for First-Pass Metabolism

A major advantage of delivering drugs through the skin is bypassing the liver's first-pass metabolism. This can enhance the bioavailability of medications that are normally rapidly degraded when taken by mouth [29].

Simple and Cost-Effective Manufacturing

Despite their advanced functionality, emulgels are surprisingly easy to produce. With the right equipment, you can scale up pretty easily without needing complex [21]

3.2 Disadvantages: Where They Fall Short

Not Always Skin-Friendly

Surfactants, especially in higher concentrations, can sometimes cause irritation. Formulators need to be careful with how much and what type they use to avoid triggering skin reactions [19].

Large Molecules Struggle

Emulgels do a great job with small to mid-sized molecules. But when it comes to bigger compounds like pedes or proteins getting through the skin barrier becomes much more difficult [25].

Temperature and Storage Sensitivity

Some emulgels don't handle heat or humidity very well. If stored improperly, you might see phase separation or thinking of the gel. That's a quality control issue that needs attention during formulation [25].

Formulation Can Be Tricky

Achieving the right balance between emulsion and gel takes time. You have to fine-tune surfactant ratios, gelling agents, and pH to get a product that is both stable and effective. It's not plug-and-play [18].

Lack of Long-Term Toxicity Data

While short-term use seems safe in most studies, we still don't have a lot of data on what happens with long-term or chronic use, especially for newer ingredients in nanoemulgels [18].

Summary Table: - The Pros and Cons

Strengths	Challenges
Excellent for lipophilic drugs	Potential skin irritation (Surfactants)
Controlled release and better penetration	Limited for large molecules like proteins
Non-greasy and cosmetically elegant	Can be unstable under poor storage conditions
Bypasses first-pass metabolism	Formulation optimization requires expertise
Easy to manufacture and scale	Long-term safety studies still limited

4. Rationale of Emulgel as a Topical Drug Delivery System

When it comes to delivering drugs through the skin, the challenge is always the same: how do we get enough of the active ingredient past the outer layer without irritating the skin or losing efficacy along the way?

Conventional topical forms like creams, lotions, and gels have served us reasonably well, but each has its limitations. Creams tend to be greasy and may not stay in place. Gels work nicely with water-soluble drugs but can't hold oily drugs very well. Lotions are easy to apply but often evaporate too quickly to be truly effective.

So, formulators started thinking-what if we combine the strengths of both emulsions and gels? That's how emulgels came into the picture.

4.1 What Emulgels Do Differently

The basic idea is simple. First, you solubilize the active drug in either an oil or water phase (depending on its solubility). You then turn that into an emulsion, using surfactants to stabilize the droplets. Finally, you blend the emulsion into a gel base. The result is a hybrid system that carries both hydrophilic and lipophilic drugs, spreads easily on the skin, and stays put long enough to do its job [17].

This design isn't just clever it's practical. The gel offers viscosity and comfort. The emulsion offers solubility and permeability. And together, they offer a way to control how fast or how deeply a drug gets absorbed.

4.2 Why This Matters in Real-World Use

Let's say you're treating localized inflammation. You need the drug to act at the site quickly. but not so fast that it wears off within an hour. You also want minimal systemic exposure. An emulgel formulation can deliver the active just deep enough; while releasing it gradually govern time. This helps maintain therapeutic levels without multiple applications per day [28].

For patients, it's more convenient. For clinicians, it's more effective. And for formulators, it provides flexibility across drug types and therapeutic areas.

4.3 Physicochemical & Biopharmaceutical Benefits

On the science side, emulgels offer some impressive properties:

- **Good solubilization of both hydrophilic and lipophilic drugs**
- **Sustained and controlled release**
- **Better stability compared to standalone emulsions**
- **Reduced first-pass metabolism, which is especially helpful for drugs with low oral bioavailability** [4]

And let's not forget emulgels are non-invasive, which is a big plus for paediatric, geriatric, and chronic care populations who may be averse to pills or injections.

4.4 Not Just for Pain and Skin Anymore

Though they started off in areas like pain relief and antifungal treatments, emulgels are now expanding into hormonal therapies, oncology, and even cosmetology. From estradiol to curcumin, more complex and sensitive compounds are finding a home in this format [15].

And the market is noticing. With patient demand for cleaner, faster-absorbing, and more natural-feeling products, companies are turning to emulgel technologies to reformulate existing drugs and even launch new delivery systems.

4.5 Regulatory and Developmental Perspective

From a regulatory standpoint, emulgels fall under semi-solid topical dosage forms, which are well understood by agencies like the FDA and EMA. However, when combined with nanotechnology or bioactive polymers, additional safety and stability data may be required [27].

Still, the path to approval is fairly straightforward especially when using well-established excipients and APIs. That makes emulgels attractive not just scientifically, but commercially.

5. Components of Emulgel Formulations

Crafting a good emulgel is a bit like baking-everything depends on the ingredients and how you combine them. You're not just mixing oil and water; you're creating a delicate system that has to be stable, spreadable, and effective at delivering a drug through the skin.

Each component in an emulgel has a job to do. Some help solubilize the drug, others thicken the system, and some keep it from falling apart over time. Getting the right mix is key to both product performance and patient satisfaction.

5.1 Oils (The Lipid Phase)

The oil phase is where you usually dissolve lipophilic (fat-loving) drugs. The type of oil you choose can make a big difference-not just for drug solubility but also for skin penetration and even the feel of the final product.

- **Natural oils** like coconut, castor, or olive oil are gentle and often add therapeutic value.
- **Synthetic oils** such as isopropyl myristate and liquid paraffin are used when you want a non-reactive, more stable base [16].

Some oils even act as mild penetration enhancers, helping the drug get past the skin's outer layer.

5.2 Surfactants and Co-Surfactants

You can't mix oil and water without some help. That's where surfactants come in they reduce surface tension and keep the emulsion stable.

- **Non-ionic surfactants** like Tween 80 and Span 20 are the go-to options because they're effective and generally non-irritating.
- **Co-surfactants** like PEG 400 or ethanol help by improving emulsification and sometimes improving skin absorption too [12].

Choosing the right pair and getting the ratio right is a balancing act. Too much can irritate the skin; too little and your emulsion falls apart.

5.3 Gelling Agents

This is what gives the emulgel its structure. Gelling agents thicken the formulation, making it easier to spread and less likely to run off the skin.

Popular choices include:

- **Carbopol 934 or 940:** These give a nice clear gel and work well in low concentrations.
- **Hydroxypropyl methylcellulose (HPMC):** More natural-feeling and used when you want a slower drug release.
- **Xanthan gum:** Often chosen for clean-label or natural formulations [30].

Gel formation is usually pH-dependent, so you'll need to tweak acidity during formulation.

5.4 Aqueous Phase

This part is mainly water, but it can also include humectants like glycerin or propylene glycol. which help with:

- Moisture retention
- Drug solubilization (for water-soluble actives)
- Skin feels and hydration

In most cases, the aqueous phase also acts as the external phase in oil-in-water (O/W) emulsions.

5.5 pH Adjusters

Skin is slightly acidic-hovering around pH 5.5-so your emulgel should match that to avoid irritation.

- Common adjusters include triethanolamine, citric acid, or sodium hydroxide.
- These also help in gelling if you're using pH-sensitive polymers like Carbopol [18].

5.6 Active Pharmaceutical Ingredient (API)

The drug itself must be compatible with the oil, surfactant, and gel system. Its solubility will dictate whether it goes in the oil phase or aqueous phase.

- Lipophilic drugs like diclofenac go into the oil.
- Hydrophilic drugs like clindamycin go into the water.

Formulators also need to be sure the drug stays stable and active over time.

5.7 Penetration Enhancers

Sometimes, you want the drug to get a bit deeper into the skin. That's when you add compounds like:

- **DMSO (dimethyl sulfoxide)**
- **Menthol or terpenes**
- **Urea or oleic acid**

These work by temporally disrupting the skin barrier but they need to be used carefully to avoid irritation [9].

Ibuprofen Emulgel

Ingredient	Function	%w/w
Ibuprofen	API	1.0
Carbopol 940	Gelling Agent	1.0
Isopropyl Myristate	Oil Phase	5.0
Span 80	Surfactant	1.0
Tween 80	Co-surfactant	2.0
Propylene glycol	Humectant	5.0
Triethanolamine	PH adjuster	q. s.
Distilled Water	Vehicle	Up to 100

6. Preparation of Emulgel

Making an emulgel isn't just about throwing ingredients into a beaker and stirring. While the process is conceptually straightforward, getting it right involves a clear understanding of what each phase is doing and how they work together. The key is to maintain stability while ensuring that the final product is smooth, effective, and skin-friendly.

Generally, the process unfolds in three broad steps: first, you prepare the gel base; then, you make the emulsion; finally, you bring the two together to form the emulgel. Simple in theory-sometimes finicky in practice.

6.1 Step 1: Preparing the Gel Base

This is your foundation. The gel gives the formulation its viscosity and helps keep the emulsion phase from separating over time.

- You start by dispersing a gelling agent-say, Carbopol 940 or HPMC-into purified water.
- The dispersion is stirred continuously, often for several hours, to avoid clumping.
- Once the gel is hydrated, the pH is adjusted (typically to 5.5-6.5) using something like triethanolamine This step activates the gel-forming process if you're using pH-sensitive polymers [31].

Letting the gel base sit for a bit after pH adjustment helps it settle into its final texture.

6.2 Step 2: Making the Emulsion

Next is the blending of oil and water phases. You should heat both the oil phase and the water phase separately to around 60–70°C to promote uniform consistency and facilitate smooth emulsification.

- The oil phase contains your lipophilic drug (if any), oil, and lipophilic surfactant (e.g. Span 80).
- The aqueous phase includes water, hydrophilic surfactant (like Tween 80), and other water-soluble ingredients.

Once both are ready, you slowly add the oil phase into the aqueous phase under continuous stirring. A high-shear homogenizer or ultra-sonicator is used to create a fine emulsion with droplet sizes as small as 100-200 nano-meters if you're going nano [34].

6.3 Step 3: Mixing to Form the Emulgel

This is where it all comes together.

- The freshly prepared emulsion is added slowly to the gel base while stirring at moderate speed usually around 500-1000 rpm.
- The goal here is gentle incorporation without introducing too much air.
- Once fully blended, the mixture is deaerated under vacuum and allowed to rest.

The final product should be smooth, free from bubbles, and stable in consistency. You can now fill it into tubes or jars for use.

6.4 Factors That Affect Quality

Parameter	Why it matters
PH	Affects both gel formation and skin compatible
Mixing speed	Too high = air bubbles; too low = poor dispersion
Oil- to- Water ratio	Impacts viscosity, stability, and drug release profile
Surfactant selection	Crucial for emulsion stability and safety
Storage Condition	Heat and humidity can destabilize the product

Even small changes in temperature or stirring rate can throw off the balance, so process consistency is key especially for large-scale production [13].

6.5 Real-World Example: Ibuprofen Emulgel

Here's a typical method for a 1% ibuprofen emulgel:

1. **Gel Base**: Disperse 1% Carbopol 940 in 60% distilled water, stir for 2 hours, adjust pH with triethanolamine.

2. **Emulsion:**

- Oil Phase: Ibuprofen + 5% isopropyl myristate + 1% Span 80.
- Aqueous Phase: 2% Tween 80+30% water, heated to 65°C.
- Mix oil into aqueous while stirring at 2000 rpm.

3. Final Step: Add emulsion to gel base gradually, mix gently, remove air under vacuum, and fill into tubes.

7. Characterization of Emulgel Formulations

After formulating an emulgel, the next big question is: how do we know it's going to work?

That's where characterization mes in. Just because a formulation looks fine doesn't mean it will perform well or remain stable over time. Evaluating both the physical and chemical properties of the emulgel ensures it delivers what it's supposed to, both in the lab and on real human skin.

These tests help answer essential questions: Is the drug evenly distributed? Will it stay stable under stress? Does it spread well? Can it actually release the drug in a controlled way?

7.1 Physical Appearance and Uniformity

The very first thing we look at is the appearance. Is the emulgel smooth? Free from lumps, air bubbles, or visible oil droplets?

- A uniform texture and color often indicate that the formulation is well-emulsified and homogenous.
- You can also spread small amount on a glass slide and observe under a microscope for consistency [2]

Even though this test is basic, it can quickly catch problems like phase separation or uneven dispersion.

7.2 pH Measurement

Since skin is naturally acidic (around pH 5.5), the emulgel's PH needs to fall in a similar range.

- A small amount of the formulation is diluted with water (1% w/v), and the pH is measured using a digital pH meter.
- Keeping the pH between 5.0 and 6.5 minimizes the risk of skin irritation [32].

It's a simple but essential test especially for sensitive skin products.

7.3 Viscosity and Rheology

Texture matters a lot. A good emulgel should be thick enough to stay on the skin, but not so thick that it's hard to spread.

- Brookfield viscometers or rotational rheometers are typically used to check viscosity.
- Most emulgels show shear-thinning behavior which means they become less viscous when you spread them, then regain their thickness afterward [25].

This property is ideal for topical use it feels smooth and spreads easily.

7.4 Spreadability

This test is exactly what it sounds like: how well does the emulgel spread?

- A small amount of product is placed between two glass slides.
- A standard weight is applied, and the time or distance the gel spreads is measured.
- The result gives a value called spread ability, which tells you if the product is suitable for quick, even application [35].

Patients generally prefer formulations that glide effortlessly especially on large or sensitive areas.

7.5 Drug Content Uniformity

To make sure the patient gets the correct dose every time, you have to confirm that the drug is evenly distributed in the product.

- A known amount of emulgel is dissolved in a solvent like methanol.
- After sonication and filtration, the drug content is measured using UV-Vis spectrophotometry or HPLC [3].

Uniform content shows the formulation process is reliable and well-mixed.

7.6 Globule Size and Polydispersity Index (PDI)

This matters most in nanoemulgels. Smaller droplet sizes improve penetration and stability.

- Dynamic Light Scattering (DLS) is used to measure the average globule size.
- PDI (Polydispersity Intex) tells us how uniform the droplet sizes are. A PDI under 0.3 is considered good [23].

Stable, small droplets lead to better bioavailability and smoother texture.

7.7 Zeta Potential

Zeta potential is a fancy term for the surface charge of the droplets. It tells us whether the emulsion is likely to stay stable or break apart.

- Measured using a Zetasizer in diluted samples.

A value above +30 mV or below-30 mV generally means the formulation is cytostatically stable [8].

This is especially important for products expected to sit on the shelf for months.

7.8 In Vitro Drug Release

To test how the drug comes out of the emulgel, we use a Franz diffusion cell setup:

- The emulgel is placed on one side of a membrane (like cellulose acetate or animal skin).
- A buffer solution on the other side mimics body fluids.
- Samples are taken at regular intervals to see how much drug has passed through.

7.9 Stability Testing

We want to know how long the emulgel will last both in the lab and on the market.

- Products are stored at different temperatures (e.g. 25°C, 40°C) and humidity levels.
- Over time, they're checked for pH, viscosity, color, and drug content [29].

Stability tests simulate what might happen during shipping, storage, or hot weather.

7.10 Skin Irritation Test

No matter how well a product performs, if it irritates the skin, it's a non-starter.

- Small patches of the emulgel are applied to animal skin (usually on Wistar rats) or via in vitro models.
- The site is observed for redness, swelling, or other reactions.

Most studies use the Draize test protocol or an OECD-approved method [33].

8. Clinical Applications and Therapeutic Use of Emulgel

Over the years, emulgels have proven themselves to be more than just a laboratory novelty. They've earned a place in real-world clinical practice by solving some stubborn problems in topical drug delivery-especially when it comes to poorly soluble drugs or those that need to stay on the skin and act over time.

Whether it's treating inflammation, fighting off infections, managing hormonal imbalances, or supporting skin care routines, emulgels offer a balanced platform that gets the job done without the greasiness or inconvenience of older formulations.

8.1 Pain, Swelling, and Inflammation

One of the most common reasons people reach for a topical product is to relieve joint or muscle pain. This is where emulgels containing NSAIDs like diclofenac, ibuprofen, or naproxen shine.

These formulations penetrate better than standard gels and often work faster. For example. diclofenac emulgel has been shown to reduce pain more effectively than its plain gel counterpart, largely because the emulsion droplets help the drug cross the skin barrier more efficiently. Patients with osteoarthritis or sports injuries often report quicker relief and longer-lasting effects with these systems [4].

8.2 Antifungal and Antibacterial Treatments

Topical fungal infections can be notoriously difficult to treat especially when the drug doesn't penetrate deep enough. Emulgels loaded with clotrimazole, ketoconazole, or fluconazole have shown improved skin deposition and antifungal activity.

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In one study, fluconazole nanoemulgel outperformed traditional cream in clearing fungal colonies and reducing inflammation The added bonus? Better spread ability and less mess during application [05].

Some emulgels are also being tested with silver nanoparticles to fight bacterial infections, especially in burn wounds and diabetic ulcers [01].

8.3 Hormonal and steroidal therapies

Hormones like estradiol and testosterone, and steroids like hydrocortisone or clobetasol, benefit from controlled release. Emulgels provide this, while also ensuring the drug stays localized to the skin or just beneath it-minimizing systemic side effects.

In hormone replacement therapy (HRT), estradiol emulgels have shown better absorption and fewer adverse effects compared to oral delivery. For eczema or psoriasis, steroid emulgels provide relief without the greasy feel of traditional ointments. [36]

8.4 Oncology and Skin Cancer Management

While still in early stages, researchers are testing emulgels for topical delivery of anticancer agents like 5-fluorouracil (5-FU) or curcumin. These treatments aim to limit tumor growth in superficial skin cancers while avoiding systemic toxicity.

A study using curcumin nanoemulgel showed a significant reduction in tumor size in mice, likely due to improved skin penetration and anti-inflammatory action [10].

This opens the door to non-invasive skin cancer treatment, particularly in elderly or palliative care patients.

8.5 Cosmetic and Dermatological Applications

Skin care is another booming area for emulgel technology. Whether it's anti-aging agents like retinol, skin brighteners like niacinamide, or moisturizers, emulgels offer an elegant solution. Their light, non-greasy texture makes them a favourite in cosmeceutical formulations. In one clinical study, a niacinamide emulgel significantly reduced melanin levels and improved skin tone over 8 weeks [20].

Plus, they're less likely to clog pores, which makes them suitable for acne-prone skin as well.

8.6 Paediatric and Veterinary Use

Emulgels are especially useful in populations that require gentle but effective treatment-like children and animals. For instance, a meloxicam emulgel has been studied in veterinary settings for pain relief in dogs and horses, offering localized action without gastrointestinal issues common in oral NSAIDs [11]. In children, mild steroid or zinc-based emulgels are being explored for conditions like diaper rash and atopic dermatitis, where comfort and safety are priorities.

Quick clinical overview

Condition	Active Ingredient	Why Emulgel?
Joint & Muscle pain	Diclofenac, Ibuprofen	Better Skin penetration, Faster relief
Fungal infections	Clotrimazole, Fluconazole	Enhanced skin retention, broad spectrum activity
Hormonal therapy	Estradiol	Avoids first-pass metabolism sustained delivery
Eczema & psoriasis	Hydrocortisone, betamethasone	Non greasy, skin-safe steroid release
Skin cancer	5 FU, Curcumin	Targeted local therapy with reduced toxicity
Skin brightening	Niacinamide, Vitamin C	Cosmetic elegance, reduced irritation
Paediatric dermatology	Zinc oxide, Mild steroids	Non irritating, easy to apply

9. Conclusion and Future Perspectives

It's becoming increasingly clear that emulgels are more than just another delivery system-they're a flexible, patient-friendly platform with potential across a range of therapeutic fields. What makes them particularly valuable is their ability to address several formulation challenges in one go. Whether it's improving drug solubility, enhancing skin penetration, or simply creating a better-feeling product, emulgels rise to the occasion.

Their strength lies in their structure. By combining an emulsion with a gel base, emulgels can deliver both hydrophilic and lipophilic drugs with decent stability and controlled release. More importantly, they provide a pleasant experience for patients-something that matters more than we often admit when it comes to long-term topical therapies.

At this point, the clinical and pharmaceutical communities have enough data to be confident in the safety, stability, and effectiveness of emulgel systems at least for conventional drugs. We've seen promising results in treating conditions like inflammation, fungal infections, eczema, and even in early experiments targeting skin cancers. Cosmeceutical companies are also embracing emulgels, drawn by their non-greasy texture and easy skin absorption.

9.1 What still Needs work

While emulgels show real promise, there are still areas that need further investigation. One of the biggest gaps lies in long-term safety studies, especially for nanoemulgels using novel excipients or active compounds. The regulatory path also gets a little murky when nanotechnology and cosmeceuticals are involved. Clearer guide nes and global harmonization could speed up approvals and commercialization [31].

From a formulation standpoint, the scale-up process remains a technical hurdle for many labs and startups. Producing a consistent emulgel at industrial scale, with tight controls over droplet size, viscosity, and stability, requires fine-tuning and often expensive equipment.

9.2 Looking Forward: Emerging Trends

As research continues, several exciting directions are coming into view:

- Nano-based emulgels are likely to dominate future development. With better control over droplet size, drug release, and skin targeting, these systems open up possibilities for high-value drugs and sensitive applications like oncology or gene therapy [26].

- The move toward biopolymer-based formulations like those using chitosan, alginate, or natural gums-will align with growing consumer demand for clean, sustainable, and skin-safe ingredients [30].

- We're also seeing early research into personalized emulgels, were drug concentration, gel viscosity, or even active ingredients can be tailored to the patient using 3D printing or Al-guided formulation systems [07].

These advances hint at a future where emulgels are not just general-use products, but precision tools in dermatology, paediatrics, wound healing, and beyond.

9.3 Result

Emulgels have evolved from niche formulations into real contenders in the world of advanced drug delivery. Their adaptability, ease of application, and ability to carry a wide variety of actives make them well-suited to modern pharmaceutical needs.

As more data accumulates and technology refines the formulation process, emulgels are likely to become even more versatile bridging the gap between conventional topical products and next-generation smart therapies. If future research stays grounded in patient outcomes, safety, and practicality, we may very well see emulgels become a staple across hospitals, homes, and even cosmetic shelves.

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