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TOPICAL GELS IN THE MANAGEMENT OF INFLAMMATION: RECENT ADVANCES AND PHARMACEUTICAL APPLICATIONS

Devanshu Dhondi*, Dr. Mamta Yadav
Bansal College of Pharmacy, Bhopal (M.P.)

Abstract:
Inflammation is a complex biological response of the body against harmful stimuli such as pathogens, damaged cells, toxic compounds, and physical injury. It plays a significant role in protecting tissues and restoring homeostasis; however, prolonged or uncontrolled inflammation may lead to chronic inflammatory disorders and tissue damage. Reactive oxygen species (ROS) are closely associated with inflammatory processes and contribute to the progression of various diseases through oxidative stress and activation of inflammatory mediators. Nonsteroidal anti-inflammatory drugs (NSAIDs) and corticosteroids are commonly used to manage inflammation by inhibiting inflammatory pathways and mediators such as cyclooxygenase enzymes and prostaglandins. Despite their therapeutic effectiveness, conventional oral administration of anti-inflammatory drugs is often associated with gastrointestinal irritation, hepatic toxicity, renal complications, and poor patient compliance.Topical drug delivery systems, particularly gels, have gained considerable attention as an alternative approach for localized treatment of inflammation due to their ease of application, improved patient compliance, controlled drug release, and reduced systemic side effects. Gels are semisolid preparations that provide better drug penetration and prolonged residence time at the site of application. Various types of gels, including hydrogels, organogels, and xerogels, are widely utilized in pharmaceutical formulations. The incorporation of penetration enhancers and suitable polymers further improves drug permeation through the skin barrier. This review article highlights the pathophysiology and mechanism of inflammation, the role of ROS in inflammatory responses, classification and mechanism of action of NSAIDs, adverse effects associated with anti-inflammatory therapy, and the importance of topical gel formulations in inflammation management. Additionally, the article discusses formulation components, classification of gels, evaluation parameters, and therapeutic applications of topical gels in pharmaceutical and cosmetic fields.

Keywords: *Inflammation, Reactive oxygen species, NSAIDs, Cyclooxygenase, Topical gel, Anti-inflammatory drugs.*

Corresponding author:
Devanshu Dhondi,
Bansal College of Pharmacy, Bhopal (M.P.)
devanshudhondi@gmail.com

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INTRODUCTION:

Inflammation is the tissue reaction and its microcirculation to a pathogenic insult. It is characterized by the generation of inflammatory mediators and movement of fluid and leukocytes from blood into extracellular tissues.

Inflammation is the immune system's response to harmful stimuli, such as pathogens, damaged cells, toxic compounds, or irradiation and acts by removing injurious stimuli and initiating the healing process (Ferrero-Miliani *et al.*, 2007). Inflammation is therefore a defense mechanism that is vital to health. Usually, during acute inflammatory responses, cellular and molecular events and interactions efficiently minimize impending injury or infection. This mitigation process contributes to restoration of tissue homeostasis and resolution of the acute inflammation. However, uncontrolled acute inflammation may become chronic, contributing to a variety of chronic inflammatory diseases (Zhou *et al*., 2016).

Causes of inflammation

Inflammation may be caused by a variety of factors including microbial infections such as bacterial, viral, fungal, and parasitic infections. Physical and chemical agents including trauma, burns, frostbite, irradiation, and exposure to toxic environmental chemicals can also initiate inflammatory responses. Immune reactions, particularly hypersensitivity reactions against environmental substances or self-tissues, are another major cause of inflammation. In addition, tissue necrosis resulting from ischemic conditions such as myocardial infarction can trigger inflammation. The presence of foreign bodies within tissues may also stimulate inflammatory reactions in the body.

Reactive Oxygen Species and Inflammation

Reactive oxygen species (ROS) are side-products of normal cell metabolism and produced in various cellular compartments like endoplasmic reticulum, mitochondria, peroxisomes. These reduced metabolites, with their strong oxidative capabilities, oxidize proteins, lipids, cellular constituents and can cause serious DNA damage. In physiological concentration ROS act as second messengers and function as signaling molecules in cell growth, cell adhesion and cell differentiation. As second messengers, ROS posttranslationally modify proteins by oxidizing redox-sensitive cystein residues (Thannickai *et al*., 2000).

An increasing number of evidence showed that reactive oxygen species are involved in initiation, progression and resolution of inflammatory responses. Chronic inflammation results in increasing ROS production. In turn, ROS regulate various types of kinases and transcription factors, such as nuclear kappa B (NF-kB), that are involved in the activation of pro-inflammatory genes (Ranneh *et al*., 2018). Overproduction of ROS during chronic inflammation results in cell and tissue injury driving to serious diseases. Neutrophil granulocytes are the primary ROS producers in the immune system, but other phagocytic cells, like macrophages, are also able to produce ROS significantly contributing to the increased ROS level.

During post-bacterial phagocytosis NADPH oxidase (NOX) bound to the phagosomal membrane is activated and produces superoxide. Altered metabolic activity, oxidative stress can also induce ROS production. Inflammatory cytokines activate STAT3, that is translocated into the nucleus, and acts as a transcription factor, regulating the transcription of inflammatory gene. Recently it was shown, that a pool of Ser727 phosphorylated STAT3 translocates into the mitochondria where it stimulates ROS production (Gough *et al.*, 2014), proving that inflammatory cytokines can directly stimulate ROS production. During chronic inflammation the ROS and inflammatory cytokine production are most probably interactive, orchestrated and synchronized and they magnify each other's effect.

Measuring Inflammation

Inflammation in the body can be assessed by measuring specific substances known as biomarkers, whose levels increase during inflammatory conditions. One of the most commonly used biomarkers is C-reactive protein (CRP). When inflammation is present, CRP levels in the blood rise significantly, and physicians often evaluate these levels to detect or monitor inflammatory disorders. CRP concentrations are generally higher in older individuals and in patients suffering from conditions such as cancer and obesity. Lifestyle factors including diet and physical activity may also influence CRP levels.

Process of Inflammation

The inflammatory process involves a series of coordinated events that can be categorized into four major stages. Initially, changes occur in the blood supply to the affected area due to alterations in smooth muscle cell function, resulting in vasodilatation. This is followed by contraction of the cytoskeleton in endothelial cells, leading to increased vascular permeability. Subsequently, phagocytic leukocytes migrate from the capillary vessels into the surrounding interstitial tissues at the site of injury or infection. Finally, phagocytosis takes place, during which invading microorganisms, damaged cells, and foreign

particles are engulfed and destroyed by phagocytic cell (Barbosa-Filho *et al*., 2006).

Mechanism of Inflammation

The inflammatory process is a combination of many pathways like a synthesis of prostaglandin, interleukin or other chemo toxin, adhesive protein receptor action, platelet-activating factors. All can act as chemotactic agonists. Inflammation initiates with any stress on the membrane or by other trigger or stimuli, these activate hydrolysis of membrane phospholipid by phospholipase A into arachidonic acid, which further substrate for cyclooxygenase and lipooxygenase enzyme and by product of these are prostaglandins PGE2, PGH2 and leukotrines like LTC4, LTB4 etc., (Villarreal *et al*., 2000). Several cytokines also play essential roles in orchestrating the inflammatory process, especially interleukin-1 (IL-1) and tumor necrosis factor-a (TNF-a). IL-1 and TNF are considered principal mediators of the biological responses to bacterial lipopolysaccharide (LPS, also called endotoxin).

They are secreted by monocytes and macrophages, adipocytes, and other cells. Working in concert with each other and various cytokines and growth factors (includingIL-8 and granulocyte-macrophage colonystimulating they induce gene expression and protein synthesis in a variety of cells to mediate and promote inflammation. Prostaglandin (PGE2) or prostacyclin (PGI2) release increase blood flow as well as increase blood vessel permeability by assisting in releasingof nitric oxide from endothelium derived releasing factor which cause again vasodilation and help in sticking platelets and other chemo toxin (bradykinin, histamine) While LTs generally are pro-inflammatory LTB4 is a potent chemotactic agent for polymorphonuclear leukocytes, eosinophils, and monocytes. In higher concentrations, LTB4 stimulates the aggregation of polymorphonuclear leukocytes and promotes degranulation and the generation of superoxide. LTB4 promotes adhesion of neutrophils to vascular endothelial cells and their transendothelial migration and stimulates synthesis of proinflammatory cytokines from macrophages and lymphocytes (Dalgleish and Byrne, 2002).

Anti inflammatory drugs

Anti-inflammatory drugs are among the most used therapeutic groups of agents worldwide (Domingos *et al*., 2019). They are used for a wide variety of indications, including pain treatment, traumatism, inflammatory and autoimmune diseases, and many of them can be obtained over the counter (Gomez-Acebo *et al*., 2018). Corticosteroids and NSAIDs are the two main groups of anti-inflammatory drugs. Corticosteroids are steroid hormones produced physiologically by vertebrates and their synthetic analogues (Ferrara *et al*., 2019), which inhibit the phospholipase A2 enzyme (Whittle, 2000). They exhibit potent anti-inflammatory and immunosuppressive effects (Pallio *et al*., 2016; Stanbury and Graham, 1998). Although certain corticosteroids (e.g., corticosterone) exhibit some antibacterial effects, only a few of them produce this action which is inferior to the current antibacterial drugs (Dogan *et al*., 2017). On the other hand, the antimicrobial activities of NSAIDs have been demonstrated in a number of *in vitro* and *in vivo* studies (Zhang *et al*., 2021; Thangamani *et al*., 2015). Their anti-inflammatory mechanism of action is through the inhibition of cyclooxygenases (COX-1 and COX-2), the key enzymes involved in prostaglandin synthesis (Bindu *et al*., 2020; Yao and Narumiya, 2019). According to the WHO List of Essential Medicines, NSAIDs are among the most frequently prescribed anti-inflammatory drugs (Bindu *et al*., 2020). In addition, they are also used as antipyretics to reduce fever and as analgesics in pain management (Bindu *et al*., 2020; Yao and Narumiya, 2019).

Evidence has shown that apart from taking antibiotics, patients are usually administered anti-inflammatory drugs to manage inflammation associated with several diseases. Thus, NSAIDs have become first-choice drugs for this purpose (Nugrahani *et al*., 2023). Because of the rich evidence of their antimicrobial effects (Thangamani *et al*., 2015; Chan *et al*., 2017), they are promising candidates for developing drugs with dual anti-inflammatory and antimicrobial activities to potentially treat combined infectious and inflammatory diseases such as MSKIs, TB and UTIs. Most importantly, using NSAIDs as a single-drug therapy could reduce the risk of adverse drug reactions caused by multiple drug co-administration. However, the results of current research on the antimicrobial effects of these drugs have yet to be sufficiently reviewed. Thus, this review summarises and critically analyses the *in vitro*, *in vivo*, and clinical data on the antimicrobial efficacy of anti-inflammatory drugs.

Table 1: Comparison of nonsteroidal anti-inflammatory drugs (NSAIDs)

NSAID	COX selectivity	Route of administration	Dose frequency
Aspirin	Nonselective	Oral	Every 4 to 6 hours (when used as an anti-inflammatory)
Celecoxib	COX-2 selective	Oral	1 to 2 times daily
Diclofenac	Cox-2 preferential	Oral, topical, rectal	2 to 3 times daily
Etoricoxib	COX-2 selective	Oral	Once daily
Ibuprofen	Nonselective	Oral, topical	Every 4 to 6 hours
Indometacin	Nonselective	Oral, rectal	2 to 3 times daily
Ketorolac	Nonselective	Intramuscular, intravenous, oral	Every 4 to 6 hours
Mefenamic acid	Nonselective	Oral	3 times daily
Meloxicam	COX-2 selective	Oral	Once daily
Naproxen	Nonselective	Oral	2 times daily
Parecoxib	COX-2 selective	Intravenous, intramuscular	Every 6 to 12 hours
Piroxicam	Nonselective	Oral	Once daily

Mechanism of Action

The main mechanism of action of NSAIDs is the inhibition of the enzyme cyclooxygenase (COX). Cyclooxygenase is required to convert arachidonic acid into thromboxanes, prostaglandins, and prostacyclins (Vane, 1971). The therapeutic effects of NSAIDs are attributed to the lack of these eicosanoids. Specifically, thromboxanes play a role in platelet adhesion, prostaglandins cause vasodilation, increase the temperature set-point in the hypothalamus, and play a role in anti-nociception.

There are two cyclooxygenase isoenzymes, COX-1 and COX-2. COX-1 gets constitutively expressed in the body, and it plays a role in maintaining gastrointestinal mucosa lining, kidney function, and platelet aggregation. COX-2 is not constitutively expressed in the body; and instead, it inducibly expresses during an inflammatory response. Most of the NSAIDs are nonselective and inhibit both COX-1 and COX-2.

However, COX-2 selective NSAIDs (ex. celecoxib) only target COX-2 and therefore have a different side effect profile. Importantly, because COX-1 is the prime mediator for ensuring gastric mucosal integrity and COX-2 is mainly involved in inflammation, COX-2 selective NSAIDs should provide anti-inflammatory relief without compromising the gastric mucosa (Chaiamnuay *et al*., 2006).

Adverse Effects

NSAIDs have well-known adverse effects affecting the gastric mucosa, renal system, cardiovascular system, hepatic system, and hematologic system.

Gastric adverse effects are likely due to the inhibition of COX-1, preventing the creation of prostaglandins that protect the gastric mucosa. The damage is more likely in a patient who has a prior history of peptic ulcers. Since it is COX-1 specific, the use of COX-2 selective NSAIDs is a lower-risk alternative (Sostres *et al*., 2010).

Renal adverse effects are because COX-1 and COX-2 facilitate the production of prostaglandins that play a role in renal hemodynamics. In a patient with normal renal function, inhibition of prostaglandin synthesis does not pose a large problem; however, in a patient with renal dysfunction, these prostaglandins play a greater role and can be the source of problems when reduced via NSAIDs. Complications that can occur include elevated blood pressure, acute renal dysfunction, fluid and electrolyte disorders, renal

papillary necrosis, and nephrotic syndrome/ interstitial nephritis (Whelton, 1999).

Cardiovascular adverse effects can also be increased with NSAID use; these include MI, thromboembolic events, and atrial fibrillation. Diclofenac seems to be the NSAID with the highest reported increase in adverse cardiovascular events (Harirforoosh *et al*., 2013).

Hepatic adverse effects are less common; NSAID-associated risk of hepatotoxicity (raised aminotransferase levels) is not very common, and liver-related hospitalization is very rare. Among the various NSAIDs, diclofenac has a higher rate of hepatotoxic effects. NSAIDs should be avoided in patients with liver dysfunction. Severe reactions, including jaundice, fulminant hepatitis, liver necrosis, and hepatic failure have been reported (Sriuttha *et al*., 2018).

Hematologic adverse effects are possible, particularly with nonselective NSAIDs due to their antiplatelet activity. This antiplatelet effect typically only poses a problem if the patient has a history of GI ulcers, diseases that impair platelet activity (hemophilia, thrombocytopenia, von Willebrand, etc.), and in some perioperative cases (Schafer, 1999).

Other minor adverse effects include anaphylactoid reactions that involve the skin and pulmonary systems, like urticaria and aspirin-exacerbated respiratory disease (Berkes, 2003; Szczeklik, 1987).

For a complete list of adverse effects for an individual NSAID, please see the StatPearls article for that particular drug.

Topical gel

Topical delivery is defined as the application of a drug-containing formulation to the skin to treat cutaneous illnesses (like acne) or cutaneous symptoms of a systemic disease (like psoriasis). The skin is one of the most accessible routes for medication administration, and topical drug delivery methods are among the most widely used. Simple solutions and ointments to multiphase nanotechnology-based products are accessible as topical medical medicines (Sabalingam and Siriwardhene, 2022; Bani and Bhardwaj, 2021).

The gel is a semi-solid preparation of tiny and big molecules dispersed in aqueous liquid carriers. Gels are semisolid systems in which colloidal particles interact (physically or covalently) inside a liquid carrier. When compared to alternative drug administration techniques, the topical/transdermal (TT) route provides several advantages, such as increased patient compliance, continuous drug delivery, fewer adverse effects, and avoidance of the hepatic first pass effect. Percutaneous absorption is an important component to address in topical drug delivery systems in order to attain and maintain consistent, systemic, therapeutic levels during the course of use (Metta *et al*., 2023).

Topical drug delivery systems are often employed when other methods of medication administration fail, or they are primarily utilised in pain treatment, contraception, and acne. Overall, topical gels provide a convenient and effective method of delivering drugs and other therapeutic agents to the skin, with minimal systemic absorption and fewer side effects compared to other routes of administration (Sharadha *et al*., 2020).

Topical drug delivery system

Topical drug delivery systems are defined as carrying specific drugs upon contact with and across the skin. The challenge with topical medications is that they cross the skin barrier. Topical drug include two basic types of products, internal and external. Internal topical preparations for local action on mucous membranes, applied orally, vaginally, or to anorectal tissues. Topical medications are sprayed, sprayed, or otherwise distributed onto skin tissue to cover the affected area (Shivam *et al*., 2022).

Advantages of topical drug delivery systems

- Avoid primary metabolism.
- Easy to use and easy to apply.
- Easy to stop medication.
- Drugs are selectively delivered to specific sites.
- Avoid gastrointestinal intolerance.
- Allow the use of drugs with short biological half-lives and narrow therapeutic windows.
- Better patient compliance.
- Self-medication (Sharadha *et al*., 2020).

Classification of gels

1] Based on number of phases:

A] Colloid Phase

Divided into two system

i) Inorganic (Two-phase) System: This system comprises floccules of small particles instead of larger molecules. The gel structure becomes unstable if the dispersed phase partition size is notably large, forming a three-dimensional structure throughout the gel. These gels must exhibit thixotropic behavior, transitioning from a semisolid to a liquid when disturbed. Examples include gels made of aluminum hydroxide and bentonite magma.

ii) Organic (Single-phase) Systems: Twisted threads in this system host large organic molecules that remain continuously dissolved. The majority of

organic gels belong to single-phase solutions, incorporating organic liquids such as plastic base and gelling agents like carbomer and tragacanth (Sharma *et al*., 2022).

2] Based on the nature of gelling agent

A] Hydrogel (Water-based): A hydrogel is a three-dimensional structure composed of hydrophilic polymers with a high capacity to interact with and retain significant amounts of water and biological fluids. This capability is attributed to various functional groups (e.g., amino (–NH2), carboxylic acid (–COOH), hydroxyl (–OH), amide (– CONH), sulfo groups (–SO3H)) present in the polymer chains. The polymer undergoes hydration to varying degrees, influenced by the nature of the aqueous medium and the polymer's composition (Toche *et al*., 2021).

Types of Hydrogels

- pH-Sensitive Hydrogel
- Temperature-Sensitive Hydrogel
- Nano Hydrogels
- Glucose-Sensitive Hydrogel

B] Organogels (With a Non-aqueous Solvent): Organogels, also known as oleaginous gels, consist of both polar and non-polar groups, with a notably high proportion of the non-polar component. They may incorporate up to 35% water, as these gels tend to swell in water. Organogelators, typically low molecular weight molecules, possess the ability to thicken in organic solvents. Organogels are thermodynamically stable, clear, viscoelastic, biocompatible, and isotropic gels composed of phospholipids and a suitable organic and polar solvent (Ahmed *et al*., 2016).

C] Xerogel: A xerogel is a dehydrated solid gel that undergoes indefinite shrinkage. It generally maintains high porosity (15-50%) and a large surface area (m2/g). Examples include strips of gum tragacanth, betacyclodextrin, dry cellulose and polystyrene, gelatin sheets, and acacia tears (Sharma *et al*., 2022).

3] Based on rheological properties

A] Plastic Gels: For instance, Bingham bodies and flocculated suspensions of aluminum hydroxide exhibit plastic flow. The rheogram plot provides the yield value, above which the elastic gel distorts and begins to flow.

B] Pseudoplastic Gels: Examples include liquid dispersions of tragacanth, sodium alginate, and Na CMC, which exhibit pseudoplastic flow. The viscosity of these gels decreases with an increasing rate of shear, without a yield value.

C] Thixotropic Gels: Gels in this category have weak bonds between particles that can be broken down by shaking. The resulting solution reverts back to a gel as particles collide and link together again. Examples include kaolin, bentonite, and agar (Parihar *et al*., 2020).

4] Based on physical nature

A] Elastic Gels: Gels like agar, pectin, guar gum, and alginates possess elastic properties. Fibrous molecules are connected at junction points through relatively weak interactions like hydrogen bonds and dipole attraction. If the molecule contains a free -COOH group, an additional bond in the form of a salt bridge (-COO-X-COO) forms between two adjacent strand networks. Examples include alginate and Carbopol.

B] Rigid Gels: These gels are formed from macromolecules with primary valence bonds connecting the framework. For instance, silicic acid molecules in a silica gel are held together by Si-O-Si-O links, resulting in a polymer structure with a network of pores (Sharma *et al*., 2022).

Formulation design

Topical gel components typically include:

- Gel forming agent or polymer
- Drug Substance
- Penetration Enhancers (Amrutkar *et al*., 2022)

1] Gel forming agent or polymer

These agents increase the viscosity of a liquid substance without substantially altering other properties like taste. The addition of a gelling agent to certain formulations results in a gelled structure. Various polymers are also employed to create the essential structural network in the gel system (Ahmed and Ali, 2016).

2] Drug Substance

Physicochemical Properties

- The drug should possess a molecular weight of less than 1000 Daltons.
- It should exhibit an affinity for both lipophilic and hydrophilic phases.
- The drug is ideally characterized by a low melting point.

Biological Properties

- The drug should exert a potent effect at a daily dose of several mg/day.
- The drug's half-life (t1/2) should be short, and it should not cause skin irritation or allergic reactions.
- Drugs susceptible to degradation in the gastrointestinal tract or inactivated by first-pass effects in the liver are suitable candidates for topical administration.

- Tolerance should not develop below the level of release close to topical administration.
- Drugs requiring prolonged use or causing undesired effects in non-target tissues can be formulated for topical administration (Patel *et al*., 2022).

3] Penetration Enhancer

Penetration enhancers are substances designed to enhance the drug's ability to penetrate the skin. Formulations often include ingredients that temporarily disrupt the highly ordered structure of the stratum corneum skin barrier. These enhancers may fluidize the lipid channels between corneocytes, alter the partitioning of the drug into skin structures, or employ other mechanisms to enhance delivery into the skin, promoting drug absorption through the skin barrier (Pate *et al*., 2022).

Properties of Permeation Enhancer

- Permeation enhancers must be non-toxic, non-irritating, and non-allergenic.
- They should be suitable for formulation into various topical preparations, compatible with both excipients and drugs.
- Ideally, permeation enhancers should be odorless, tasteless, colorless, and cost-effective.
- They should exhibit no pharmacological activity within the body, meaning they should not bind to receptor sites (Ahmed and Ali, 2016).

Evaluation of gels

A] pH Measurement

The pH of different gel formulations is determined using a digital pH meter. 1 g of gel is dissolved in 100 ml of freshly prepared distilled water and stored for two hours. pH measurements for each formulation are conducted in triplicate, and average values are calculated (Patil *et al*., 2019).

B] Homogeneity

All formulated gels undergo testing for homogeneity through visual inspection after being poured into the container. The gels are assessed for their appearance and the presence of any impurities (Amrutkar *et al*., 2022).

C] Grittiness

Microscopic examination is conducted on all gel formulations to check for the presence of any particulate matter.

D] Stability

The stability of gels is assessed through freeze-thaw cycling. In this method, the sample is kept at 4°C for 1 month, then at 25°C, and finally at 40°C for another month to examine for syneresis (Badola *et al*., 2021).

E] In vitro Dissolution Studies

In-vitro dissolution studies are carried out using the USP paddle apparatus. The dissolution medium (900ml) maintained at 37°C ± 0.5°C and stirred at 50 rpm. Samples (5ml) are withdrawn at specified time intervals (10, 20, 30, 40, 50, 60, 90, 120 min), and sink conditions are maintained by replacing fresh media. These withdrawn samples are then analyzed using a UV spectrophotometer. Now, the percentage of drug release is calculated based on the absorbance values obtained from the UV spectrophotometer.

F] Drug Content

To assess drug content, 1g of the gel or jelly sample is taken and mixed in a suitable solvent. Different concentrations are prepared by suitable dilutions after filtering the stock solution, and absorbance is measured. The drug concentration is then determined using an equation obtained through linear regression of a calibration curve. Alternatively, it can be evaluated by spectroscopy using a UV spectrophotometer.

G] Skin Irritation Test

For the skin irritation test, the Swiss albino mice strain and Guinea pigs (400- 500gm) of either sex are employed as animal models. Hairs are removed using a skin removal cream, and the skin is cleaned with spirit. In this test, three mice are used where normal saline, blank gel, and the formulated gel are applied to check for irritation in animals (Samundre *et al*., 2020).

H] Spreadability

To assess spreadability, 0.5 g of the gel is applied within a pre-marked circle of 2 cm diameter on a glass plate. A second glass plate is then placed over it, and a weight of about 500 g is rested on the upper glass plate for 10 minutes. The increase in diameter due to gel spreading is noted.

I] Viscosity

The viscosity of the gel is measured using the Brookfield Viscometer (Kewade *et al*., 2023).

Applications of Gels

- Gel applications include the pharmaceutical and cosmetic sectors. Gels are administered directly to the skin, mucous membrane, or eye to provide local action.
- They serve as long-acting drug implants or intramuscular injections.

- Cosmetic gels are found in a variety of goods such as shampoos, deodorants, dentifrices, and skin and hair care products (Sharma *et al*., 2022).

CONCLUSION:

The topical gel improves skin absorption and thereby enhances bioavailability. Furthermore, it has high patient acceptance. According to clinical evidence, topical gel is a safe and effective therapy choice for the treatment of skin-related disorders. Because of improved patient compliance, topical medication delivery systems have been increasingly popular in recent years. The whole study concludes that gels are a potential semisolid topical treatment that may be extensively employed.

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