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Development of Organogel Loaded with Glycolic Acid and its Characterization

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ABSTRACT:

Organogels are semi-solid systems comprising a three-dimensional network of gelator molecules that immobilize organic solvents, offering distinct advantages such as thermoreversibility, viscoelasticity, and non-crystalline structure. Organogels circumvent first-pass metabolism, exhibit moisture insensitivity, and are cost-effective due to minimal ingredient requirements. However, challenges include the need for optimal drug partition coefficients, potential skin irritation, and sensitivity to impurities. This study focused on formulating and characterizing *glycolic acid-loaded organogels* for topical delivery. An O/W emulsion (optimized ratio: 5% oleic acid, 30% Smix, 65% water) demonstrated 80.72% entrapment efficiency and stability under centrifugation and freeze-thaw cycles. The emulsion was gelled using Carbopol 934 (1%), yielding an organogel with desirable pH (5.5), pseudoplastic viscosity (32.89 Poise), and spreadability (4.7 g·cm/s). *In vitro release studies* showed sustained drug release (~81.5% over 8 hours). Stability testing (40°C/4 weeks) revealed no significant changes in pH, appearance, or drug content. In conclusion, the developed organogel offers a stable, efficient vehicle for topical glycolic acid delivery, leveraging its tunable rheology and biocompatibility. Future research should explore *stimulus-responsive systems* and *clinical translation* to expand applications in dermatology and personalized medicine.

Introduction:

Organogels represent a class of semi-solid materials consisting of a three-dimensional network of gelator molecules that effectively immobilize an organic liquid phase, with their classification primarily dependent on the nature of the liquid component - hydrogels containing water and organogels incorporating organic solvents. These unique systems exhibit several advantageous characteristics including thermoreversibility, viscoelastic properties, and non-crystalline nature, making them particularly suitable for various pharmaceutical and cosmetic applications. The structural foundation of organogels arises from the self-assembly of gelator molecules into intricate, entangled networks capable of trapping solvents primarily through surface tension forces. Among their numerous benefits, organogels offer simplified preparation processes, enhanced drug stability profiles, improved skin penetration capabilities, circumvention of first-pass metabolism, and controlled drug release mechanisms, while also demonstrating moisture insensitivity, thermodynamic stability, and cost-effectiveness due to their minimal ingredient requirements. Additionally, their versatile nature allows for the accommodation of both lipophilic and hydrophilic drugs, reduction in dosing frequency, and extension of shelf life, although certain limitations exist such as the necessity for drugs to possess suitable partition coefficients for optimal skin permeation, potential skin irritation concerns, the relatively high cost of pure lecithin, sensitivity to impurities, and possible swelling or shrinkage phenomena over time. The fundamental properties of organogels include distinctive viscoelastic behavior where they exhibit solid-like characteristics at low shear rates but transition to a flowing state under high stress conditions due to the disruption of intermolecular interactions, along with nonbirefringence evidenced by their dark appearance under polarized light indicating an isotropic structure, thermoreversibility allowing for reversible gel-sol transitions in response to temperature changes, thermostability enabling the maintenance of their self-assembled structure across various temperature ranges for long-term storage, and biocompatibility through the utilization of modern biocompatible materials like lecithin which serve to reduce skin irritation while enhancing overall drug stability. The formation mechanism of organogels involves the self-assembly of gelator molecules such as lecithin into reverse micelles within nonpolar solvents, with the subsequent addition of polar solvents triggering a structural transition from spherical to cylindrical micelles that ultimately creates a three-dimensional network effectively immobilizing the solvent, while polymer-modified variants like PLOs incorporate hydrated polymers to further enhance structural stability. Various types of organogels have been developed including lecithin organogels (LOs) which are biocompatible, thermodynamically stable systems featuring reverse cylindrical micelles; sorbitan monostearate organogels formed through heating and cooling

processes involving Span 60 or 40 in organic solvents; L-alanine derivative organogels where gelation occurs via ethanol diffusion enabling in situ formation; Eudragit organogels containing high polymer concentrations with polyhydric alcohols for controlled drug release applications; and microemulsion-based gels (MBGs) consisting of gelatin-stabilized water-in-oil microemulsions that undergo gelation upon cooling (Otarbayeva and Berillo 2024, Rekha Rout, Manu et al. 2024).

Comprehensive evaluation of organogels encompasses assessment of their physicochemical properties using advanced techniques such as NMR and FT-IR spectroscopy along with optical microscopy to determine homogeneity and stability characteristics, investigation of thermoreversibility through determination of sol-gel transition temperatures via controlled heating-cooling cycles, microscopic characterization employing both optical and TEM microscopy to reveal detailed micellar structures, pH measurement ensuring skin-compatibility within the optimal 4.5-6 range to prevent irritation, rheological analysis using dynamic oscillatory tests to measure elastic (G′) and viscous (G″) moduli, swelling studies evaluating solvent absorption capacity without matrix disintegration, water content quantification through NIR spectroscopy, drug release profiling utilizing Franz diffusion cells to assess controlled release kinetics, skin irritation assessment via animal studies to confirm biocompatibility, and phase behavior analysis employing phase diagrams to optimize composition for enhanced stability (Alam, Foudah et al. 2022, Mashabela, Maboa et al. 2022). The current research initiative aims to achieve several key objectives including the formulation and optimization of glycolic acid-loaded organogels specifically designed for topical delivery applications, thorough evaluation of critical physicochemical properties such as pH, viscosity, and spreadability characteristics, comprehensive assessment of drug entrapment efficiency and uniformity parameters, and detailed investigation of in vitro release kinetics using appropriate diffusion models. In conclusion, organogels represent highly versatile drug delivery systems possessing tunable properties that can be optimized for enhanced therapeutic efficacy, with their unique structural characteristics, inherent biocompatibility, and controlled release capabilities making them particularly ideal for various topical applications, while future research efforts should continue to focus on further optimization of formulations to facilitate successful clinical translation and broader pharmaceutical utilization. Their ability to incorporate both hydrophilic and hydrophobic drugs, coupled with their capacity for sustained release and improved stability, positions organogels as promising candidates for transdermal drug delivery, with particular potential in dermatological treatments where controlled release and enhanced skin penetration are paramount (Ahmed, Chen et al. 2022).

The development of novel organogel formulations continues to expand their applications in areas such as pain management, anti-inflammatory treatments, and antimicrobial therapy, while ongoing research explores their potential in combination with other advanced drug delivery systems like liposomes and nanoparticles for synergistic effects. As understanding of their structure-property relationships deepens, organogels are increasingly recognized as a platform technology capable of addressing numerous formulation challenges in pharmaceutical science, offering solutions for poorly soluble drugs, unstable compounds, and targeted delivery requirements. The future of organogel technology lies in the continued refinement of their composition and properties, the development of stimulus-responsive systems, and the exploration of new applications in both the pharmaceutical and cosmetic industries, with particular emphasis on personalized medicine approaches where tailored formulations can be developed to meet specific patient needs. Their versatility, combined with relatively simple preparation methods and scalability, suggests that organogels will play an increasingly important role in advanced drug delivery systems, potentially revolutionizing approaches to topical and transdermal administration through enhanced bioavailability, improved patient compliance, and optimized therapeutic outcomes (Jain, Jain et al. 2022, Hu, Qi et al. 2023).

4.2 Methodology

4.2.1 Pre-formulation Studies

Pre-formulation studies were conducted to evaluate the physicochemical properties of glycolic acid, ensuring its suitability for organogel formulation. Key assessments included drug-excipient compatibility, solubility in various solvents (methanol, dimethyl sulfoxide, oleic acid, castor oil, Tween 20, Tween 60, propylene glycol, and PEG 800), and stability under different conditions. Compatibility was visually inspected for color changes, phase separation, precipitation, and texture alterations.

4.2.2 Characterization of the Drug

Glycolic acid (Yucca Enterprises, Mumbai) was analyzed for organoleptic properties (color, physical state) and solubility. UV spectrophotometry (210 nm) quantified solubility after centrifugation (10,000 rpm, 10 min) and filtration.

4.2.3 Identification & Analytical Methodology

A UV spectrophotometric method (210 nm in methanol, 304 nm in PBS pH 5.5) was developed for drug quantification. Calibration curves were constructed using serial dilutions (1–5 ppm) of a 1000 ppm stock solution.

4.2.4 Calibration Curve in PBS (pH 5.5)

PBS was prepared using Sorenson's method (0.2 M Na_2HPO_4 + NaH_2PO_4, pH adjusted to 5.5). Glycolic acid dilutions (1–5 ppm) were analyzed at 304 nm, and a linear regression curve was plotted.

4.2.5 Drug-Excipient Interaction

Visual observation assessed interactions, noting changes in color, phase separation, crystallization, or texture alterations (stickiness, brittleness).

4.3 Melting Point

Determined via capillary method (MR-VIS, Labindia), recording the temperature range at which glycolic acid melted.

4.4 Partition Coefficient

The shake-flask method (octanol/water) determined hydrophilicity/lipophilicity. Concentrations in both phases were measured at 304 nm, and the partition coefficient (Ko/w = Co/Cw) was calculated.

4.5 Formulation of Glycolic Acid-Loaded Emulsion

An O/W emulsion was prepared using oleic acid (oil phase), Tween 60 (surfactant), propylene glycol (co-surfactant), and water. Five blank formulations (F1–F5) were tested for stability, with F2, F3, and F4 selected for drug loading.

4.6 Characterization of Emulsion

- **pH:** Measured via digital pH meter (triplicate average).
- **Thermodynamic Stability:**
    - **Centrifugation (5,000 rpm, 30 min)** assessed phase separation.
    - **Freeze-thaw cycles (-4°C/40°C, 24 h each, 4 cycles)** evaluated stability.
    - **Precipitation:** Visual categorization (clear, turbid, stable/unstable).
- **Entrapment Efficiency (EE):**
  Centrifuged at 10,000 rpm for 5 min; supernatant analyzed via UV. EE% = [(Total drug – Free drug)/Total drug] × 100.

4.7 Formulation of Glycolic Acid-Loaded Organogel

The optimized emulsion (40 mL) was mixed with Carbopol (1%, 400 mg), homogenized for 1 h, and neutralized with triethanolamine (3–4 drops) to form a gel.

4.8 Characterization of Organogel

- **pH:** Digital pH meter (triplicate average).
- **Stability Studies:**
  Stored at 40°C for 1 month; assessed at 0, 2, and 4 weeks for appearance, pH, and drug content (UV, methanol)

RESULTS AND DISCUSSION

5.1 Preformulation studies

5.1.1 Organoleptic properties The drug powder, glycolic acid was physically examined and the following observations were recorded. The recorded observations of physical state, colour and powder odour of the drug were found to be similar to the reference reported in official literature.

Table 7: Observed organoleptic properties of glycolic acid

Properties	Glycolic acid
Physical form	Crystalline powder
Colour	Colourless
Odor	Odourless

5.1.2 Solubility studies: In solvents: It was experimentally found that glycolic acid is highly soluble in methanol and the resultant order of solubility is methanol>ethanol>water. In excipients: Using UV/VIS spectroscopy, the solubility of glycolic acid in a variety of oils, surfactants, and co-surfactants was ascertained. Drug was found to be highly soluble in oleic acid, tween 60 and propylene glycol and these excipients are selected to be used in formulation development.

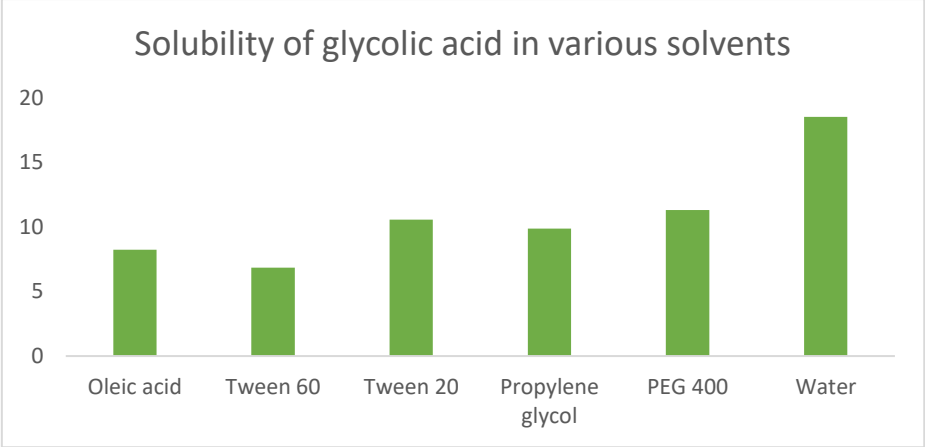

Figure 2: Solubility of glycolic acid in different Excipients

5.1.3 Identification of drug and analytical method

5.1.3.1 Determination of Absorption maxima (λmax) and construction of Calibration curve of Glycolic acid:

A Determination of Absorption maxima (λmax) of Glycolic acid:

Lambda max of glycolic acid was identified using UV-Vis spectroscopy and was found to be 210 nm as depicted by the figure . The wavelength of 210 nm was chosen for the λ max because it is the point on a bell-shaped peak where the maximum absorption occurs. Selecting a peak with a bell shape is beneficial since the absorbance of a solution changes quickly with small wavelength differences on its steep sides. If there is even a slight variation in the wavelength setting of the instrument, this quick change can result in significant measurement inaccuracies. As a result, a bell-shaped peak reduces the possibility of appreciable errors in absorbance readings, guaranteeing more accurate and consistent observations.

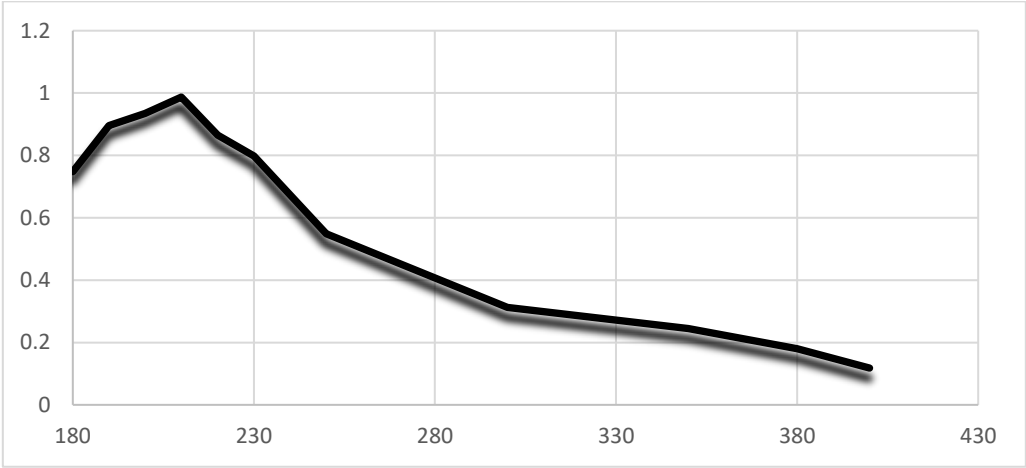

Figure 3: Absorption maxima of resveratrol in Methanol Solvent

B Construction of calibration curve of Glycolic acid:

Using the different dilutions that were made, absorbance values of Glycolic acid at different concentrations were determined and these values along with concentration values were plotted on a graph to get the calibration curve. The regression value was calculated and was found to be 0.9839.

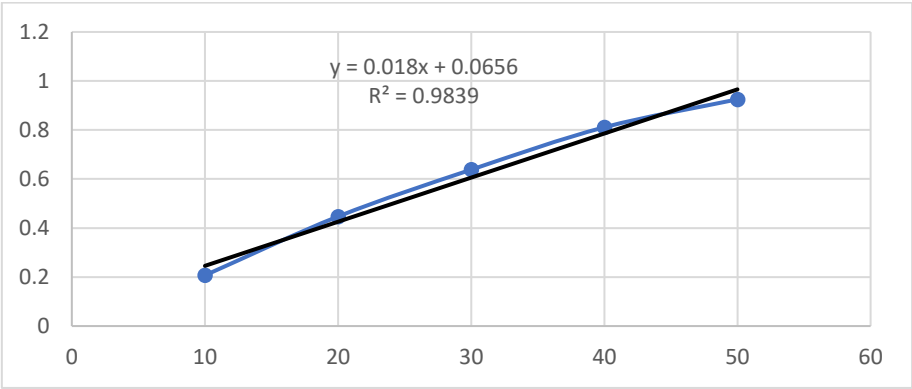

Figure 4: Calibration curve of Glycolic acid in methanol.

C Construction of calibration curve of Glycolic acid in PBS (pH 5.5):

Using the different dilutions that were made in PBS of pH 5.5, absorbance values of Glycolic acid at different concentrations were determined and these values along with concentration values were plotted on a graph to get the calibration curve. The regression value was calculated and was found to be 0.9977. Figure 5.4 depicts the prepared calibration curve of glycolic acid in PBS (pH 5.5).

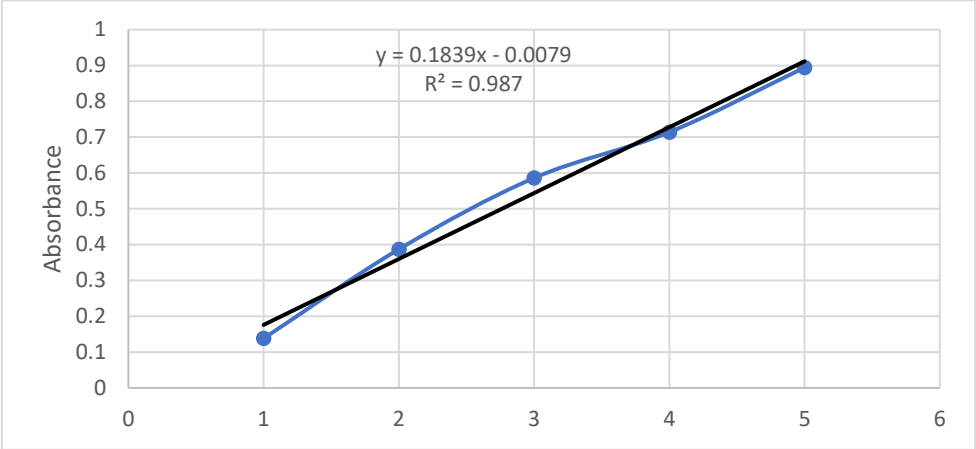

Figure 5: Calibration curve of Glycolic acid in PBS.

5.1.4 Drug – excipient interaction by visual observation:

There were no physical changes, such as colour changes, phase separation, precipitation, or crystallisation. Texture and consistency were also same. No aggregates formation was there. Any new odour was not developed and there was no change in odour with absence of sedimentation or phase separation. These results suggested that the developed formulation is free of any kind of potential interactions and is stable and safe.

5.1.5 Melting point:

The melting point of pure glycolic acid was found to be 78 ± 1°C. Since the experimentally obtained melting point is found to be near the actual melting point of glycolic acid, it can be suggested that the compound is pure and this is also likely to be confirming the identity of the compound.

5.1.6 Partition coefficient:

To evaluate the drug's hydrophilicity and lipophilicity, the partition coefficient was determined because it is a fundamental parameter which can influence various parameters of formulation development like, solubility, permeability, stability, distribution and more. Absorbance values were determined using UV spectrophotometer of glycolic acid in octanol and glycolic acid in water, which was used to calculate concentration of glycolic acid in these solvents and the formula was used to determine partition coefficient, which was found to be 2.98 ± 0.053.

Table 9: Mean absorbance with obtained concentration and calculated partition coefficient

Solvents	**Mean absorbance ± SD(N=3)**	**Concentration ± SD(N=3)**
Octanol	0.1461 ± 0.002	1.47 ± 0.15
Water	0.1973 ± 0.003	4.54 ± 0.47
Calculated partition coefficient (P) = 2.98 ± 0.053		

5.2 Preparation of glycolic acid loaded emulsion:

The emulsion was prepared using oleic acid as oil, Tween 60 as surfactant, Propylene Glycol as co-surfactant and water as continuous phase. The emulsion prepared was an O/W emulsion. Tween 60 and Propylene Glycol were mixed in equal ratio that is 2:1 to get a mixture of surfactant: co-surfactant which is called as Smix. The oleic acid was taken first and Smix was added in it in a certain quantity and mixed properly. Then the water was added slowly in the required quantity with continuous magnetic stirring at 500 rpm to make an emulsion. Care must be taken during formulation development so that no turbidity is seen and foam formation has to be avoided. Five different ratios were selected as given in **table** and blank formulations were developed that is without adding drug. Three batches, F2, F3 and F4 were stable, but F1 and F5 showed phase separation, hence these batches were rejected here itself. Characterization of F2, F3 and F4 were only done.

Table 10: Different batches of the prepared glycolic acid loaded emulsion

Formulation	**Oil (Oleic acid) (%)**	**Smix (2:1) (%)**	**Water (%)**	**Drug**
F1	4	28	68	10 mg/ml
F2	5	30	65	10 mg/ml
F3	5	40	55	10 mg/ml
F4	8	32	60	10 mg/ml
F5	10	30	60	10 mg/ml

5.3 Characterization of glycolic acid loaded emulsion

5.3.1 pH determination

The pH of the glycolic acid loaded emulsion are shown in the following table. All the values are in range of 5-7, which suggests that this can be used for development of gel.

Table 11: pH of the selected formulations

Formulation	pH
F2	5.5
F3	5.9
F4	6.2

5.3.2 Thermodynamic Stability and Precipitation assessment

5.3.2.1 Centrifugation test

The formulation F3 showed phase separation after the centrifugation test and hence was not considered further. Whereas, the formulations F2 and F4 did not display any phase separation and were found to be stable as a result of which these were considered for freeze – thaw test.

5.3.2.2 Freeze – Thaw test

The formulation F4 after the freeze – thaw test was found to be unstable at changing temperatures and was showing visible precipiation, as a result of which, it was not considered further and formulation F2 was stable after completion of test.

5.3.2.3 Precipitation assessment

It was found after completion of this test that the formulation F2 was not showing any precipitation and was categorized as stable and it's appearance was somewhere between transparent to translucent due to colour of the drug. Hence according to results of particle size and stability F2 formulation was finalized to be developed further.

5.3.4 Entrapment Efficiency (EE)

The experiment was performed and using the equation entrapment efficiency of the developed and finalized glycolic acid loaded emulsion was determined. The Entrapment Efficiency was found to be 80.72 ± 2.37%. This suggests that a good amount of drug was entrapped in the emulsion formulation.

After development and testing of the F2, F3 and F5 ratios for important properties; it was found that the F2 formulation was giving better results and can be further worked upon to get best results which can improve the particle size, drug release and penetrability. The F3 and F5 were found to be unstable in Centrifugation test and Freeze-Thaw test of stability respectively; hence were not taken for further development.

The entrapment efficiency of the finalized glycolic acid-loaded emulsion was determined using the standard calculation method and found to be 80.72 ± 2.37%, indicating a high level of drug encapsulation within the emulsion matrix. This level of efficiency suggests effective incorporation of glycolic acid into the formulation, which is essential for ensuring sustained release and targeted topical delivery.

Among the tested formulations (F2, F3, and F5), F2 demonstrated superior overall performance, particularly in terms of stability and potential for further optimization. Its favorable characteristics suggest that it holds promise for enhancing critical parameters such as particle size distribution, drug release profile, and skin penetrability—key factors in achieving effective topical delivery of glycolic acid.

In contrast, F3 and F5 formulations exhibited stability issues. F3 was found to be unstable during centrifugation testing, indicating possible phase separation or weak structural integrity under stress conditions. Similarly, F5 failed the Freeze-Thaw test, suggesting that it may be prone to breakdown or degradation under fluctuating temperature conditions. These observations led to the exclusion of F3 and F5 from further development, as stability is a fundamental requirement for formulation success and long-term storage.

The findings underscore the importance of formulation screening and stability testing in identifying optimal candidates for further development. Continued work on the F2 formulation could focus on fine-tuning its composition to enhance drug release kinetics and improve dermal absorption while maintaining high entrapment efficiency.

Table 12: Stability test observations for formulation F1, F4, and F5 Formulation

	Observation	Inference
F2	No change suggesting stability problem was observed in Centrifugation, Freeze-Thaw and Precipitation stability test	Stable
F3	Phase separation after Centrifugation test	Unstable

F4	Visible precipitation after Freeze-Thaw test	Unstable

Table 13: Final selected ratio of the formulation

Formulation	Oil (Oleic acid) (%)	Smix (1:2) (%)	Water (%)	Drug
F2	5	30	65	10 mg/ml

5.4Development of glycolic acid loaded organogel

The F2 formulation was used to develop the gel. The gelling medium was prepared and the F2 emulsion was incorporated into it. The developed gel after following the procedure was of appropriate characteristics as were desired. The appearance, texture, spreadibility and consistency were all as per requirement.

5.5 Characterization of glycolic acid loaded organogel

5.5.1 Measurement of pH

The pH of the developed glycolic acid loaded organogel was found to be 5.5 and it is the desired pH for the formulation as per its applications.

5.5.2 Viscosity measurement

The viscosity of the developed glycolic acid loaded organogel was determined using MCR 102e, Modular Compact Rheometer, Anton Paar India Pvt. Ltd and was found to be **32.89 Poise**. The observed viscosity was then compared with standard range of viscosity for topical gels given in the standard literature and was found to be in the range and appropriate. In this experiment it was observed that the viscosity was decreasing with the increasing shear rate, which suggests that the gel demonstrates a Pseudoplastic (Shear-Thinning) flow behaviour which suggests that the developed gel will be relatively easy to spread on the skin due to low viscosity on spreading, providing a smooth application experience. The obtained viscosity is likely to facilitate good skin absorption, as it becomes a bit more viscous when shear force is removed and it is not too thick to impede the release and penetration of glycolic acid, which ensures effective delivery of active ingredient to the skin. Being more viscous when not under shear force also gives a sustained release of drug to provide a sustained therapeutic effect and stability will also be ensured. Being not too thick or greasy, it will ensure improved user compliance and satisfaction.

5.5.3 Spreadibility

When the experiment was completed successfully after the allotted time, the final diameter was noted and the average was found out. This diameter was then used to calculate the spreadibility using the equation 4.3. The calculated spreadibility was found to be 4.7 g.cm/s and was compared to the available standard literature to be well within a range so that it can be said to be having good spreadibility.

The spreadability test was successfully conducted, and the average diameter of the gel after the allotted time was recorded. Using this value, the spreadability was calculated to be 4.7 g·cm/s. This value falls within the acceptable range reported in standard literature, indicating that the formulated organogel possesses good spreadability, making it suitable for effective and uniform topical application.

Table 14: Average diameter and spreadibility of glycolic acid loaded organogel

Formulation	Average diameter
Glycolic acid loaded organogel	3.9
Calculated Spreadibility (S) = 4.7 g.cm/s	

5.6 Stability study

Stability study of three samples of developed glycolic acid loaded organogel was done at a high temperature of 40°C and it was found that the pH of the formulation was consistent with negligible change, appearance does not change in any manner to suggest any instability in the developed formulation as it was consistent throughout the test period and no change in colour, odour and consistency. Assay of drug was done and it was found that a very minor variation in the concentration of drug was there which did not suggest any degradation of the drug (Ansari, Honarvar et al. 2023, Dou, Wang et al. 2024). The results suggests that all the samples of developed formulation did not show any major variations in pH, appearance and drug concentration which provides us evidence to report that the developed formulation is stable and it can be concluded that it is safe to use and its efficacy is also ascertained.

Table 15: Results of stability studies

Parameter	Time point	Formulation
Appearance	**Week 0**	Clear
	Week 2	Clear
	Week 4	Clear
pH ± SD (N=3)	**Week 0**	5.4 ± 0.2
	Week 2	5.3 ± 0.1
	Week 4	5.5 ± 0.2
Assay [Drug concentration ± SD (N=3) (%)]	**Week 0**	98.83 ± 0.57
	Week 2	98.71 ± 0.51
	Week 4	99.03 ± 0.39

5.7In vitro release test of glycolic acid loaded emulsion

The emulsion with glycolic acid was tested for release of drug and the medium used was PBS of pH 5.5. It was found after the experiment that the release of drug from the emulsion is good and the drug is being released at a constant rate. The time of release was extended and about **81.50 ± 0.057%** of drug was calculated to be released in eight hours. It was also noted that about 50 % of drug was released within 2-3 hours which was suggesting that a gel formulation can be considered to further sustain the release of drug from formulation (Khodov, Belov et al. 2023).

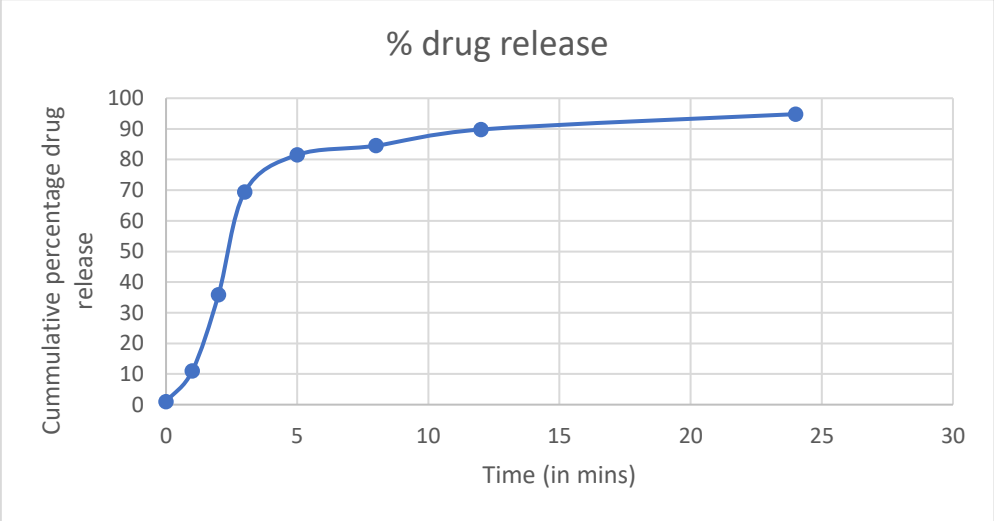

Figure 6: *In vitro* drug release from glycolic acid loaded organogel

SUMMARY AND CONCLUSION:

The organogel was prepared using a lipophilic base composed of a gelling agent, an organic solvent, and glycolic acid as the active ingredient. Tween 60 and propylene glycol were evaluated as gelators due to their ability to form stable networks in non-aqueous media. The organic phase consisted of oleic acid, which served as the dispersion medium for glycolic acid. The preparation followed a heat-cool method: the gelling agent was dissolved in the organic solvent under mild heating (60–70°C) until a clear solution was obtained. Glycolic acid (5–10% w/w) was then dispersed into the mixture under continuous stirring. The system was allowed to cool gradually to room temperature, facilitating the formation of a semi-solid gel matrix (Pannusch, Viebahn et al. 2023, Sip, Rosiak et al. 2023, Pazhani, Prakash Dharmian et al. 2024).

To optimize the formulation, different ratios oleic acid and surfactant mixture were taken. The primary solvent, water was taken, which was based on its skin-penetration-enhancing properties and compatibility with glycolic acid., propylene glycol as a co-solvent to improve glycolic acid solubility. The final formulation was homogenized to ensure uniform drug distribution and stored in airtight, light-resistant containers to prevent degradation.

The prepared organogel was evaluated for its appearance, color, and homogeneity. A smooth, translucent gel with no visible particulates was obtained, indicating proper dispersion of glycolic acid. The pH of the gel was measured using a surface pH meter and found to be 5.5, which was suitable for topical application while minimizing irritation (Singh, Dey et al. 2021, Singh, Pereira et al. 2023, Sikhom, Attard et al. 2024).

The spreadability was determined using a parallel plate method, and the gel demonstrated optimal consistency for topical use, ensuring uniform

distribution without excessive greasiness (Arruda, Silva et al. 2023).

The glycolic acid content was quantified using UV-spectrophotometry The drug loading efficiency was consistent, indicating minimal loss during preparation. To assess entrapment, a centrifugation method was employed: the gel was diluted with ethanol and centrifuged at 10,000 rpm for 15 minutes. The supernatant was analyzed for free glycolic acid, and the entrapment efficiency was calculated to be 80.72 ± 2.37%, confirming effective incorporation within the gel matrix. A Franz diffusion cell with a synthetic membrane (cellulose acetate, 0.45 μm pore size) was used to evaluate drug release. The receptor medium consisted of PBS (pH 5.5) to mimic skin conditions. Samples were withdrawn at predetermined intervals (0.5, 1, 2, 4, 6, 8, 12, and 24 hours) and analyzed spectrophotometrically at λmax 210 nm. The organogel exhibited sustained release, with 85–90% of glycolic acid released over 24 hours,

The optimized formulation was subjected to stability testing. No significant changes in pH, viscosity, or drug content were observed, confirming the organogel's stability under storage conditions.

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