*S. Afr. J. Chem.*, 2026, 80, S118–S124
https://journals.co.za/content/journal/chem/

# Development and Characterization of Self-Micro-Emulsifying Drug Delivery System (SMEDDs) for Gliclazide and Acyclovir

**Reshma Pol[1]* and Nishika Yadav[1]**

[1]*School of Biotechnology and Bioinformatics, D.Y. Patil Deemed to be University, Navi Mumbai, Maharashtra, India.*

**ABSTRACT**

**Star anise is a spice used in food industries. Oil based microemulsions were prepared by using essential oil extracted from star anise buds combined with surfactants, co-surfactants and drug of interest. A stable micro emulsion from the oil was produced by using constructive concentrations. Tween 80 was taken as the surfactant, Mixture of glycerine and lecithin as co- surfactant, and star anise oil were combined in different ratios to create eight self-micro-emulsifying formulations. Drugs like Gliclazide (Diamicron) (antidiabetic) and Acyclovir (antiviral) were studied, respectively. To determine the self-microemulsion region, pseudo-ternary phase diagrams were created. Thermodynamic studies were carried out to check the stability of microemulsions. In addition, various characteristic features were measured such as viscosity, self-emulsification time, zeta potential and droplet size determination. As in vitro drug dissolution study along with physicochemical parameters revealed stable microemulsion formation enhancing the bioavailability of drugs and site-specific absorption. Therefore, star anise oil can be a promising drug delivery system for drug bioavailability enhancement along with improved solubility and dissolution rates.**

**KEYWORDS**

**essential oil, bioavailability, drug delivery systems, microemulsions**

Received: 9 October 2025 Revised: 15 April 2026 Accepted: 9 May 2026

## INTRODUCTION

Star anise is most widely used spice in food industries and breweries because of its distinctive smell and taste. Although it is used to treat a wide range of illnesses, such as flu, gastrointestinal disorders, and respiratory disorders, the effectiveness of the majority of these uses has not been sufficiently studied. 85% to 90% of the weight of star anise essential oils is made up of trans-anethole, paramethoxyphenyl propene. Sesquiterpenes, phenylpropanoids, lignans, and flavonoids are among the bioactive components of star anise that are thought to be responsible for its pharmacological actions. The other components are β-phellandrene, α-diterpene, limonene, estragole, safrol, terpene, pinene, and terpineol.[1] Using Star anise as the source of oil for the formulation of microemulsions takes into consideration its features and abilities to improve health. Research suggests that the overall star anise composition and most importantly anethole, contribute to numerous medical uses like sedative, antispasmodic, anti-inflammatory, antibacterial, anticancer, and antioxidant qualities.[2] Another effective feature of anethole is the ouzo effect. Many research studies have proved that when anetholes are dissolved in water they form a cloudy oil-in-water emulsion, which is more stable. The pharmaceutical industry makes extensive use of the ouzo effect to co-precipitate medications and polymers into precisely sized nanoparticles.[3] Such a method can improve the drugs, which have low solubility levels inside the body, by enhancing that a greater amount of the active compound successfully enters the body fluids for absorption.

Drug bioavailability is the measure of the amount of the active compound reaching the target site or rather entering the body fluids for its absorption. The value depends mostly on parameters like the dosage amount, size, its target site, its design and process of manufacturing.[4] Different drugs have different absorption levels in the body depending on the ways of its administration: inhaled, oral, buccal, sublingual, rectal, parenteral, and topical and the form of drug i.e., in form of tablet or capsule. Thus, these aspects often cause a problem in case of the patients with weak rate of absorption and gastric emptying abilities.[5] In pharmaceuticals, microemulsions are most prominent drug delivery systems because these are thermodynamically stable unlike standard emulsions. It consists of an oil, surfactant, co- surfactant and drug. Microemulsions are effective because the formulations are readily prepared upon dissolving all the required constituents in correct concentrations even in low quantities and are generally in range of 10 to 300 nm.

In this research, star anise essential oil was used along with Tween 80, mixture of glycerine and lecithin with gliclazide and acyclovir.[6] Drugs that are commercially available but with low bioavailability were used. Gliclazide, a class II, antidiabetic drug has 85% bioavailability and is the most excessively needed medicine for the treatment of type 2 diabetes mellitus.[7] Acyclovir, a class III, antiviral drug has 15–30% bioavailability and is required to treat diseases like herpes, chicken pox, shingles and different types of infections.[8] Therefore, it's crucial to increase their bioavailability.

## EXPERIMENTAL

### Extraction of oil

Star anise buds (five) were crushed using a mortar and pestle and were grounded into fine pieces. 5 g of grounded powder was utilized for the extraction of essential oil using a Soxhlet apparatus and ethanol as the solvent. It was carried out at 78 °C (boiling point of ethanol) until the solution in the thimble turned colourless. After 8-9 cycles, the distillate was collected and subjected to ethanol removal using rotary vapor. The final essential oil was collected in 100 mL Pyrex bottles.

### Solubility of the drugs

The solubility studies of the drugs of interest were carried out by adding different amounts of drug (gliclazide and acyclovir) to various concentrations of oil, surfactant (Tween 80), and co- surfactant (glycerine and lecithin) as indicated in (Table 1) and mixed by vortex. The ratios of oil: surfactant: co-surfactant at 1:1:1, 2:2:1, and 1:2:1.5. The ultra-sonication (Mumbai, India) of the mixture tubes was carried

*To whom correspondence should be addressed
Email: reshma.kamble@dypatil.edu

ISSN 1996-840X Online / South African Chemical Institute / http://saci.co.za/journal
© The Author(s) Published under a Creative Commons Attribution 4.0 International Licence (CC BY 4.0)
https://doi.org/10.17159/0379-4350/2026/v80se1a12

**Table 1:** Combinations for solubility of Gliclazide and Acyclovir

| Sr. No. | Star Anise Oil (mL) | Tween 80 (Surfactant) (mL) | (Glycerine + lecithin) (Co- surfactant) (mL) | Drug (mg) |
|---|---|---|---|---|
| F1 | 2 | 2 | 2 | 2 |
| F2 | 1 | 1 | 1 | 0.5 |
| F3 | 2 | 2 | 1 | 0.5 |
| F4 | 1 | 2 | 1.5 | 1 |

out for 15 minutes and then centrifuged at 5000 rpm for 15 min at 4 °C. The drug concentration in the mixture was determined using a UV-VIS spectrophotometer (Shimadzu 1800) at 243nm.[9]

### Pseudo–ternary phase diagram

To identify the emulsification area for selected components, ternary phase diagrams are largely employed. In ternary diagrams, the ratio of one component varies while the concentrations of the other two are fixed. For each phase of investigations, oil, surfactant, and co-surfactant are grouped in four distinct mixtures. A pseudo ternary plot was constructed taking oil and surfactant in a 1:9 to 9:1 ratio, which is titrated with water in increasing quantities in different glass bottles.[10] The plot consists of a triangle and each axis and was denoted by one axis representing oil, another axis as a combination of surfactant and co-surfactant and a third axis as water. Each corner was in percentage formats for all the chemicals or solvents being used. In order to define phase boundaries precisely, different combinations of oils and surfactants were formulated for the study to cover the maximum ratios of oil and surfactant. The plot was constructed using online software like XLSTAT and CHEMIX School 3.6.[11]

### Formulation of a self- emulsifying drug delivery system

The formulation was obtained by using co-surfactant i.e., glycerine and lecithin mixture in a beaker and drug was added to it. This was dissolved in an isothermal water bath set at 60 °C for 1-2 hrs. The addition of oil was done, and the mixture was allowed to cool at 37 °C. After cooling, the surfactant (Tween 80) was added into this mixture and ultra-sonicated for 15 min. The final mixture was kept at 37 °C for 24 hrs to check for turbidity or any visible phase differences.

### Physicochemical characterisation and evaluation of self-emulsifying formulation

There are different tests and measurements to characterize the prepared formulations of microemulsions.

#### *Thermodynamic stability*

The prepared formulation was divided into three equal parts in three different centrifuge tubes with temperature differences. One was kept at 4 °C in a refrigerator, the second was kept at room temperature, and third tube was kept at 40 °C. These tubes were kept at their respective temperatures for not less than 48 hrs. After 48 hrs, the formulations were centrifuged at 3500 rpm for 30 min at 4 °C. Absorbance was recorded using UV- spectrophotometer at 243nm. The samples in which phase separation is not observed were subjected to freeze thaw cycles between -20 °C and 40 °C.[12] The thermodynamically stable formulations will not show any change in visual description.[13] Following each stress condition, the formulation was assessed for any changes in drug content, and physical appearance. Under these circumstances, a thermodynamically stable SEDDS should exhibit no appreciable changes, suggesting that it can hold onto its characteristics over time.

#### *Visual tests*

Each formulation was poured into beaker containing 200 mL distilled water at 37 °C. The solution was vortexed for a minute and kept for 24 hrs to check any phase difference or precipitation. For further studies, mixtures that showed very little phase separation throughout the course of two hours were utilized.[14]

#### *Self-emulsification time*

Self-emulsification time was determined; the formulation was added in a beaker or flask containing 100 mL of the medium consisting of 50 mL 0.1N HCl and 50 mL distilled water. The self-emulsification time was determined by stirring the solution at 100 rpm using a magnetic stirrer. Measure the time required to form a uniform solution after complete dilution of formulation into water. Emulsification time for microemulsions of Gliclazide and acyclovir were measured separately.[15]

#### *Viscosity*

The viscosity of the formulation was recorded using a Brookfield DVE viscometer (Ametek, US). 50 mL of the formulation was placed in a beaker. S62 spindle was carefully immersed it into the liquid with the required speed.

#### *Droplet size and PDI*

Both the emulsions were diluted with a ratio of 1:2500 with distilled water and were vortexed. The particle size was determined using Malvern particle size analyzer (Malvern Panalytical, UK) in Diya Laboratories, Navi-Mumbai.

#### *Zeta potential*

The zeta potential of the self-emulsified micro formulations of the drugs, Gliclazide and acyclovir diluted with a ratio of 1:2500 with distilled water and were vortexed. The zeta potential was measured using Malvern Zetasizer (Malvern Instruments, UK).[16]

#### *In-vitro dissolution studies*

The dialysis tubing method was performed to analyze in vitro dissolution studies. A dialysis membrane of avg. diameter 25 mm, avg. flat width 37 mm approx. capacity 5 mL/cm with cut-off value 1200 to 1400 Da was used. The dialysis bag was placed in 0.2 M phosphate buffer of pH 6.8 at 50 rpm at 37 °C, removed, and then by clipping one end of the bag the formulation was added into the bag and sealed by clipping from the other end. Avoid any air bubbles in between. The bag was placed again in the buffer for the desired period of time. The released drug concentration into the buffer was recorded at frequent time intervals using UV- spectrophotometer at 243 nm.[17]

#### *Kinetic studies*

A kinetic study of the formulation was accomplished by plotting a graph for the concentration of the drug against time. The drug concentration level was evaluated over an increasing period of time. The buffer was taken at the desired time and the absorbance was recorded with a UV-spectrophotometer at 243 nm. The results indicate the order of reaction for the drugs.

## RESULTS AND DISCUSSION

### Extraction of star anise oil

A volume of 100 mL of the total star anise oil was obtained by repeating the extraction for 3 to 4 times using Soxhlet apparatus for 5 gm of grounded star anise samples. The estimated extraction yield of the

essential oil from star anise obtained was 48.4%. The obtained oil was collected in Pyrex bottles and stored in the refrigerator for further use.

## Solubility of drugs

The solubility of Gliclazide was determined at different concentrations of Tween 80, glycerine and lecithin. A stable mixture was obtained, depicting that gliclazide is partially soluble and higher amount of drug concentration will lead to unstable microemulsions causing precipitation of the drug. The solubility for gliclazide was found to be higher in F1, whereas, for Acyclovir it was found to be F4. Thus, for microemulsions formation using gliclazide at low concentration of drug was used. Similarly, the solubility of Acylovir was determined, and lower drug concentrations were preferred for the study. High concentrations of hydrophobic medications can be dissolved by the amphiphlic surfactants. In lipid formulations, hydrophilic co-surfactants can be used because they are known to lessen the oil/water interface and promotes self-assembly of microemulsion.[17]

The solubility of Acyclovir, BCS III with high water solubility was found to increase in formulation F4 due to the increased proportion of Tween 80 as the surfactant, as it facilitates the formation of stable emulsion and co-surfactants with smaller droplet size (Figure 1). It promotes long term physical stability and prevents coalescence (droplet merging). The solubility of Gliclazide, BCS II, and poorly water-soluble drug, was found to be better in F1 with 1:1:1 ratio of oil surfactant and co-surfactant. Its solubility is enhanced at equal ratios of all three components involved in the SMEEDS formulations. Tween 80 acts as the primary surfactant and the co-surfactants play synergistic role in the formation of emulsions. Glycerine, a viscosity modifier, improves stability, and lecithin favours formation of flexible interfacial layer around the droplets, preventing coalescence. Their combinations enhance drug solubility and bioavailability.[18]

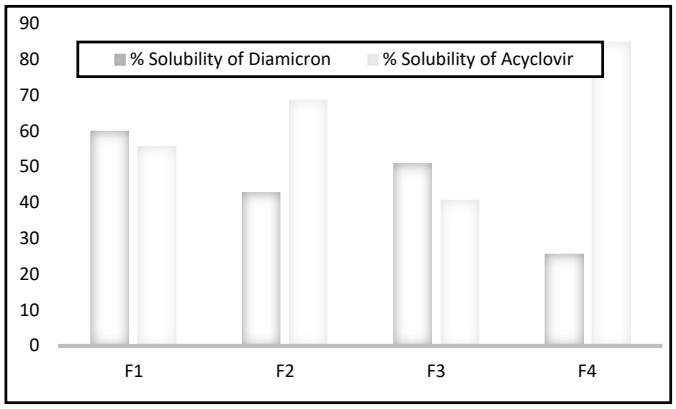



**Figure 1:** Solubility test for Gliclazide and Acyclovir

## Pseudo–ternary phase diagram

Pseudo ternary plot was constructed for Gliclazide microemulsions in 1:9 and 9:1 ratio of surfactant, oil and water (Table 2).

The pseudo-ternary plot was used to detect the regions of emulsification in order to understand the stability of the microemulsions formed.[19] It helps us to know if the amount of oil, surfactant and co-surfactant taken is correct. The above pseudo-ternary phase diagram (Figure 2 and 3) depicts that stable microemulsions were formed with correct concentrations of oil, surfactant and co-surfactant since the shaded area falls in the lower half of the triangle along with oil in water form of microemulsions. The resulting micro-emulsion is biphasic in nature if it appears in the lower half and it is monophasic in nature if it appears in the upper half of the triangle. The oil is at 9.95%, surfactant 80% and water is 5.46%. Similar plots were carried constructed for Acyclovir, in same ratio in 1:9 to 9:1 of surfactant, oil and water.

## Formulations

Performing the experimental protocol, a clear uniform solution was prepared and transferred in a capped test tube. This formulation was later used for characterization of the microemulsions.

## Physicochemical Characterisation

### *Thermodynamic testing*

The drugs precipitation in the mixture of excipients was assessed using a thermodynamic stability analysis. To evaluate the stability of the SEDDS, thermodynamic stability testing entails exposing it to a range of stress conditions, including centrifugation, and freeze-thaw cycles.[18] For Gliclazide and Acyclovir, the centrifuged solutions showed no phase distribution (Table 3) so were exposed to three freeze thaw stress cycles. It was found that every SEDDS formulation was physically stable and that no chemicals precipitated into the lipid matrix resulting in a single uniform phase.

There was no change in the visual appearance of the thermodynamically stable formulations.[19] Similar results were obtained by Srinivas *et al.,* 2013 for Repaglinide (BCS II) SEEDS formulation an oral hypoglycaemic drug with physically stable homogenous liquid SEEDS formulations after thermodynamic stability studies were carried out.[20] Jaiswal *et. al.,* 2014 also noted analogous findings regarding solid SMEEDS of telmisartan, an anti-hypertensive agent, which exhibited thermodynamically stable systems formed at specific concentrations of oil, surfactant, and co-surfactant, without phase separation, demonstrating kinetic stability.[21]

### *Visual tests*

Visual observation helped in the evaluation of self-emulsification. After SEDDS of Gliclazide and acyclovir were diluted with distilled

**Table 2:** Formulation table for i) Gliclazide and ii) Acyclovir

**(i)**

| Sr. No. | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Star Anise Oil (mL) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Tween 80 (mL) | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Water (mL) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 1.0 |
| Drug (mg) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**(ii)**

| Sr. No. | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Star Anise Oil (mL) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Tween 80 (mL) | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Water (mL) | 0.5 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Drug (mg) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

water each and mixed well using vortexed. These formulations were observed after 24 hrs. No phase differences were observed in both the micro-emulsions stating that those were stable emulsions. In general, the presence of a clear, isotropic, transparent solution indicates the formation of a microemulsion, whereas the development of a macroemulsion is indicated by an opaque, milky white appearance. A stable formulation is indicated by the absence of precipitation and/or phase separation.

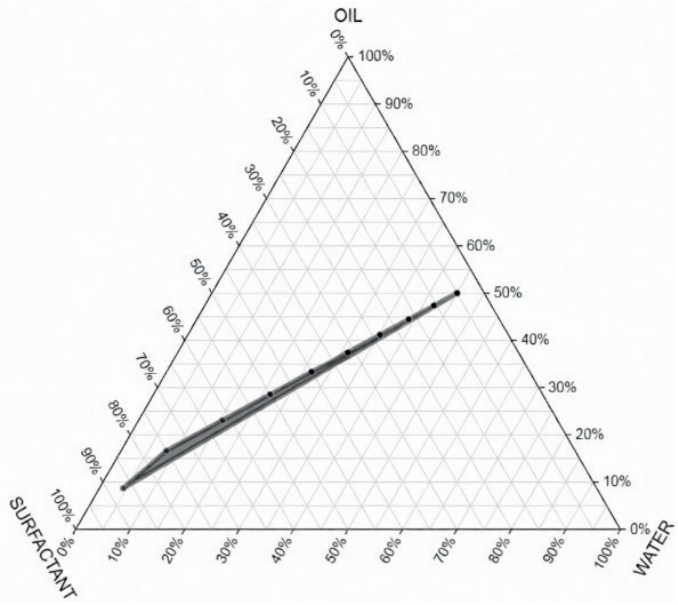



**Figure 2.** Pseudo-Ternary plot of Gliclazide

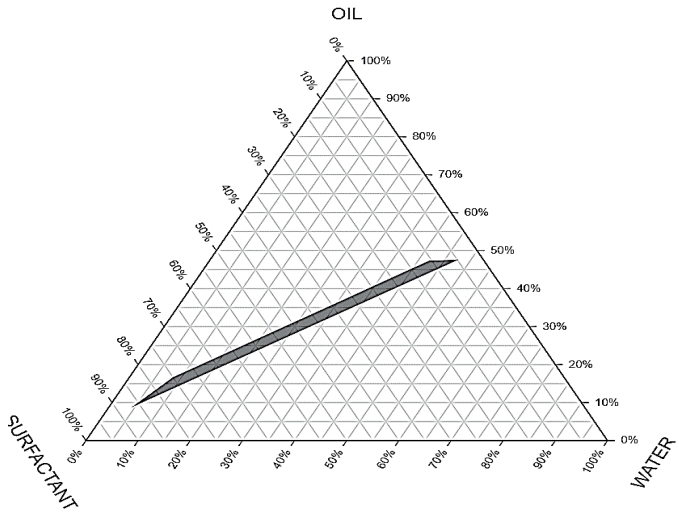



**Figure 3.** Pseudo-Ternary plot of Acyclovir

### *Self-emulsification time*

The oil/surfactant and oil phase ratios affect how long it takes to emulsify a mixture. This is ascertained by means of a basket dissolution apparatus, which assesses transparency upon agitation subsequent to the addition of a formulation dropwise into a basket filled with water. The self-emulsification time for Gliclazide microemulsion was estimated to be around 2 sec to 4 sec approximately, and for acyclovir microemulsion time taken was 5 sec to 6 sec approximately. The self-emulsification time helps us to understand the effectiveness and quality of the formulated microemulsions.

### *Viscosity*

The viscosity of diluted SEDDS formulations was measured using a Brookfield viscometer, a rheometer with a revolving spindle S62. The viscosity of both Gliclazide and acyclovir micro emulsion both was recorded as 0.7%, 21.00 cPat 10 rpm. Both the formulations followed a similar composition of surfactant, co-surfactant leading to comparable rheological behavior. The ideal viscosity for microemulsions should be within the range of 10-100cP. A low viscosity indicates low in oil content and presence of short chain fatty acids, namely lauric acid, which thus offer easy flow ability of microemulsions.[22]

### *Droplet size and PdI*

The extent of the particle size distribution is gauged by the Polydispersity Index (PDI). For SEDDS, a more uniform particle size distribution is indicated by a lower PDI value (< 0.3), which guarantees stability and consistent performance. A larger particle size distribution is indicated by a high PDI (>0.3), which could cause instability or variability in medication release.[23, 24] The graph (Figure 4) showed a single peak that indicates uniform droplet size. The PDI values of the microemulsions for Gliclazide were 0.421 with particle size in the range from 10 to 12 dnm as in Figure 4a. Whereas, the values for the formulated microemulsions for acyclovir were 0.585 with a particle size in the range from 10 to 18 dnm as in Figure 4b.

### *Zeta potential*

Zeta potential for Gliclazide micro emulsion was determined by Malvern zeta sizer (Figure 5a). The measured zeta potential was in the range of - 0.365. Similarly, zeta potential for acyclovir (Figure 5b) was - 0.426. The conductivity of the formulation for Gliclazide was 0.08 ms/cm, and that for Acyclovir was 0.12 ms/cm. It indicates moderate conductivity with low ionic content and presence of non-ionic surfactants, thus analysing them to be weakly conductive oil water nano-emulsions. The negative zeta potential (Table 4) indicates electrostatic repulsion that prevents coalescence and flocculation that improves the physical stability of the nanoemulsion. However, the zeta potential values are below -20 mV that indicates a risk of instability between both the nanoemulsions and are more likely to

**Table 3:** Thermodynamic stability study for Gliclazide and Acyclovir

| SMEEDS Formulation | Formulation Code | Centrifugation (3500rpm) | Freeze thaw cycle | |
|---|---|---|---|---|
| | | | -20°C | 40°C |
| Gliclazide | F1 | Passed | Passed | Passed |
| | F2 | Passed | Passed | Passed |
| | F3 | Passed | Passed | Passed |
| | F4 | Passed | Passed | Passed |
| Acyclovir | F1 | Passed | Passed | Passed |
| | F2 | Passed | Passed | Passed |
| | F3 | Passed | Passed | Passed |
| | F4 | Passed | Passed | Passed |

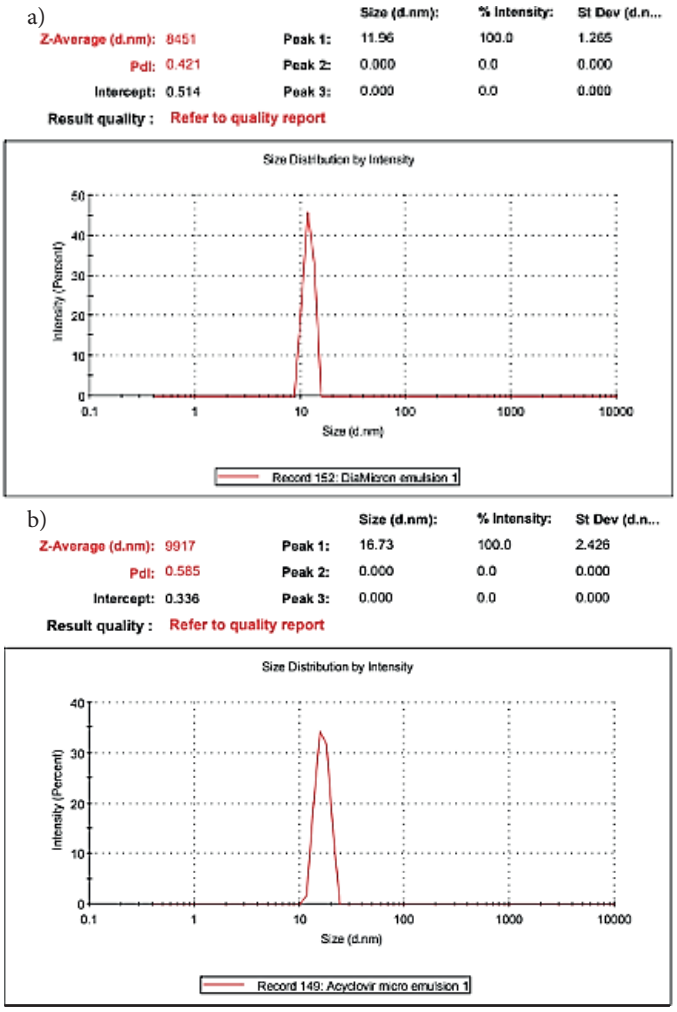



**Figure 4.** Droplet size and PDI obtained for a) Gliclazide b) Acyclovir

**Table 4:** Data representing the size, Poly dispersity Index and Zeta Potential

| Drug emulsion of | Size (d.nm) ± Std. dev. | Polydispersity Index (PdI) | Zeta Potential |
|---|---|---|---|
| Gliclazide | 11.96±1.26 | 0.421 | -0.365 |
| Acyclovir | 16.73±2.43 | 0.585 | -0.426 |

aggregate and settle out of solution. However, nanoemulsions for acyclovir are better in comparison to Gliclazide.

Kunwarpuriya *et. al*., 2020 also reported a droplet size of 21.07 d.nm and PdI of 0.37 for SMEEDS of HMG CoA reductase inhibitor, Fluvastatin sodium.[25] Jeevana & Sreelakshmi, 2011 also developed SNEEDS and enhanced the dissolution of poor water soluble drug, Flutamide, antiandrogenic agent used for prostate cancer. The researchers also utilized Tween 20 and sesame oil for the formulation of SNEEDS.[26, 27]

## In vitro dissolution studies

The bioavailability and consequent therapeutic efficacy of pharmacological preparations are determined by a crucial parameter: drug dissolution. The in vitro dissolution studies was done using the dialysis tubing method at different time periods, and the absorbance, i.e., the concentration of the drug released into the buffered solution, was determined using a UV spectrophotometer at 243 nm for both drugs. The optimized SEDDS formulations of both drugs' release kinetics are demonstrated in detail in this graphic depiction.

The in vitro dissolution studies, as depicted in Figure 6, help us to gain knowledge about the formulation development for immediate or controlled release. It provides an understanding of the amount

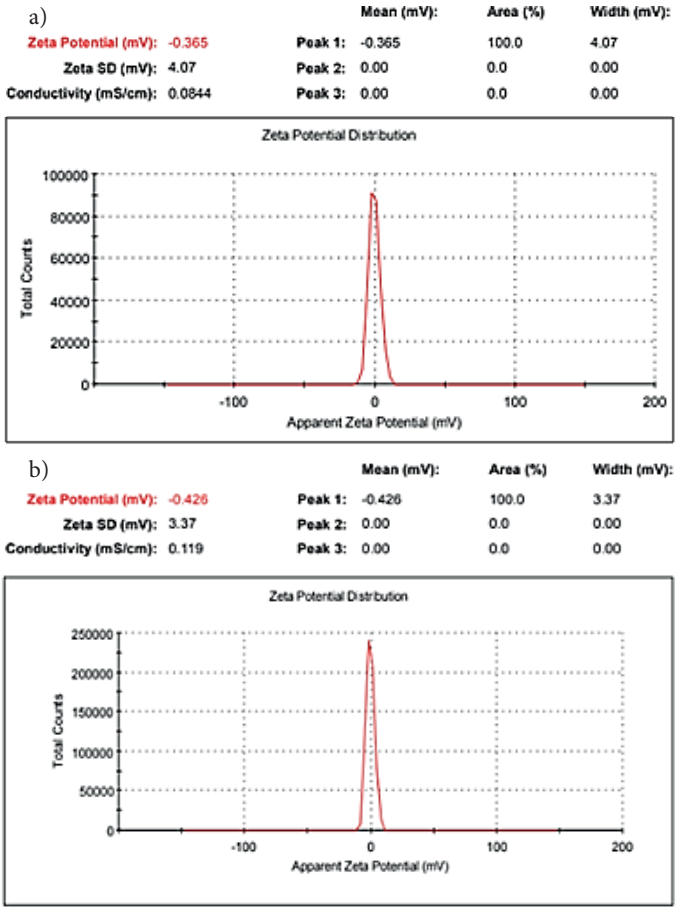



**Figure 5.** Zeta potential for a) Gliclazide and b) Acyclovir

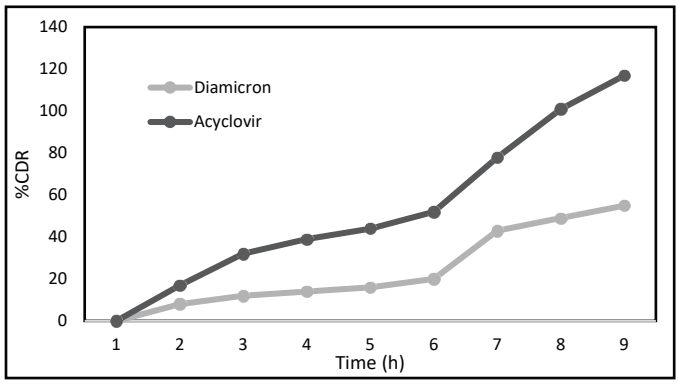



**Figure 6.** In vitro drug dissolution studies of Gliclazide and Acyclovir

required of the excipients (oil, surfactant, and co-surfactant) by knowing the proportion at which the drug should be added to form stable solutions. It's critical for poorly soluble drugs, especially those of BCS class II and IV, thus ensuring that a drug product is safe, effective and consistent throughout the therapy. Similar findings, were reported by Nipun and Islam, 2014 for SEEDS of gliclazide and reported optimal drug diffusion and significant reduction in plasma glucose level after oral administration in albino mice.[28] Singh *et al*., 2011 also reported that the in vitro dissolution obtained for all solid dispersion was 3-8 times more as compared to pure drug due to enhanced solubility and dissolution of ketoprofen in donor compartment.[29] Mudrika *et al*., 2026 also observed maximum drug release of 92% of Flunarizine (intra-nasal agent) in 10h due to optimized surfactant (Tween 80) and co-surfactant (PEG 400) ratio and reduced droplet size enhancing diffusion rate. Thus, the results were found to be consistent with studies reported by other researchers.[30]

### Kinetic studies

Figure 7 depicts the kinetic studies by measurement of the drug concentration in the formulation over an increasing time period using UV spectrophotometer at 243 nm. The kinetic studies provide an insight into the release kinetics that is important in designing sustained or controlled release drugs. The prepared formulations followed first-order kinetics when the concentration was plotted against increasing time intervals. Thus, the rate of reaction gradually increased over time and is dependent on the concentration of the drug. It helps us to understand the drugs in vitro dissolution studies by showing the reaction characterization of the drug of interest.

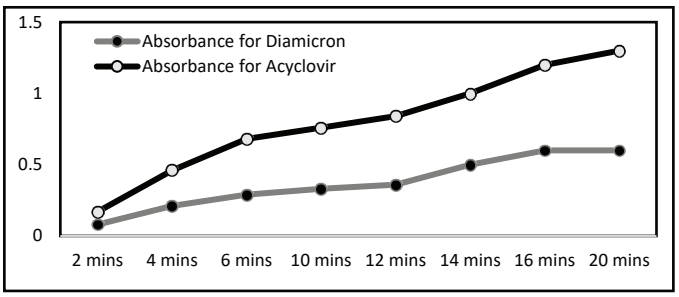



**Figure 7:** Kinetic studies of microemulsions of Gliclazide and acyclovir

## CONCLUSION

A stable self-emulsifying micro emulsion is a propitious way for drugs with poor solubility, Gliclazide. The SMEEDS contains a mixture of star anise oil, Tween 80, glycerine, and lecithin mixture, efficiently helping in enhancing the bioavailability of the drugs like gliclazide and acyclovir. The formulation components and their proportional ratios were determined through solubility study, pseudo-ternary plots, droplet size, particle size analysis, zeta potential, and in vitro dissolution studies. The formulated microemulsions of gliclazide and acyclovir were thermodynamically stable and showed no phase differences. The liquid SMEEDS of both the drugs showed enhanced in vitro drug release. A thorough look at all of these factors makes sure that SMEDDS can safely and effectively deliver drugs to patients. Thus, this research strongly shows that self-microemulsifying drug delivery systems can be used along with essential oils obtained from food items for the enhancement of drugs with low solubility.

## SUPPLEMENTARY MATERIAL

There is no supplementary information. All the data are presented in the article.

## ACKNOWLEDGEMENT

The authors would like to thank the director, Dr. Debjani Dasgupta, and the management of the School of Biotechnology and Bioinformatics, D. Y. Patil Deemed to be University, Navi- Mumbai for their encouragement and support.

## AUTHOR CONTRIBUTIONS

Nishika Yadav carried out the experimental measurements and analysis, and preparing the original draft, Reshma Pol was involved in conceptualization, visualization, validation, writing reviewing and editing the article.

## STATEMENT OF CONFLICT OF INTEREST

The authors declare that they have no conflict of interest to declare that are relevant to the contents of this article.

## DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES

During the preparation of this work, the author(s) used QuillBot to correct grammar and Turnitin for plagiarism checks. The author(s) reviewed and edited the content of the manuscript for publication.

## AUTHORS ORCID

Reshma Pol: http://orcid.org/0000-0003-1628-5568
Nishika Yadav: http://orcid.org/0009-0008-0304-4267

## REFERENCES

1. Chen JN, Zhang YY, Huang X, Wang H-P, Dong X, Zhu B, Qin L. Analysis of Lipid Molecule Profiling and Conversion Pathway in Mandarin Fish (Sinipercachuatsi) During Fermentation via Untargeted Lipidomics. J Agric Food Chem. 2023;71(22):8673–8684. https://doi.org/10.1021/acs.jafc.3c00769.
2. de la Rubia Fernández L, Orizaola Ingelmo A, Hurtado Barace L, Lozano de la Torre MJ. Intoxicación por anís estrellado. An Pediatr (Barc). 2009 Dec;71(6):581–582. https://doi.org/10.1016/j.anpedi.2009.08.012.
3. Goubault C, Iglicki D, Swain RA, McVey BFP, Lefeuvre B, Rault L, Nayral C, Delpech F, Kahn ML, Chevance S, et al. Effect of nanoparticles on spontaneous Ouzo emulsification. J Colloid Interface Sci. 2021;603:572–581. https://doi.org/10.1016/j.jcis.2021.06.104.
4. Kahlweit M. Microemulsions. Science. 1988;240(4852):617–621. https://doi.org/10.1126/science.240.4852.617.
5. Constantinides PP. Lipid microemulsions for improving drug dissolution and oral absorption: physical and biopharmaceutical aspects. Pharm Res. 1995; 12: 1561-1572. https://doi.org/10.1023/A:1016268311867.
6. McGavin JK, Perry CM, Goa KL. Gliclazide Modified Release. Drugs. 2002;62(9):1357–1364. https://doi.org/10.2165/00003495-200262090-00010.
7. Gupta AK, Mishra DK. Preparation and evaluation of self-emulsifying drug delivery system of anti-hypersensitive drug valsartan. Int J. Pharm Life Sci. 2011;2(3):633–639.
8. Sapra K, Singh SK. Formulation development and optimization of self-emulsifying drug delivery system of Meloxicam. Int J Pharm Pharm Sci. 2013;5(2):524–530.
9. Maulik JP, Natvarlal M. Formulation and evaluation of self-micro emulsifying drug delivery system of lovastatin. Asian J Pharm Sci. 2010;5(6):266–275. https://doi.org/10.31838/ecb/2022.11.09.010.
10. Beg S, Swain S, Singh HP, Patra CN, Rao ME. Development, optimization and characterization of solid-self nano emulsifying drug delivery systems of valsartan using porous carriers. AAPS PharmSciTech. 2012;13(4):1416–1427. https://doi.org/10.1208/s12249-012-9865-5.
11. Sharma S, Sharma AD. Formulation and evaluation of self-emulsifying drug delivery system of Ibuprofen using Castor oil. Int J Pharm Pharm Sci. 2011;4(3):299–302.
12. Reddy SM, Muhammad FHS. Solubility enhancement of Fenofibrate, A BCS class II drug, byself-emulsifying drug delivery system. Int Res J Pharm. 2011;2(11):173–177.
13. Akula S, Gurram AK, Devireddy SR. Self-Microemulsifying Drug Delivery Systems: An Attractive Strategy for Enhanced Therapeutic Profile. Int Sch Res Notices. 2014;2014:964051. https://doi.org/10.1155/2014/964051.
14. Mahajan H, Sheikh T. Design and development of solid self-micro emulsifying drug delivery system of Fenofibrate. Int J Pharm Pharm Sci. 2011;3(4):163–166.
15. Puttachari S, Kalyane NV, Duttagupta S. Comparative Bioavailability of Cefuroxime Axetil from Tablets and Self-Microemulsifying Drug Delivery Systems in Rats. Int J Pharm Sci Nanotechnol. 1970;9(4):3375–3382. https://doi.org/10.37285/ijpsn.2016.9.4.8.
16. Bakhle SS, Avari JG. Development and characterization of solid self-emulsifying drug delivery system of cilnidipine. Chem Pharm Bull (Tokyo). 2015;63(6):408–417. https://doi.org/10.1248/cpb.c14-00326.
17. Singh AK, Chaurasiya A, Singh M, Upadhyay SC, Mukherjee R, Khar RK. Exemestane loaded self-microemulsifying drug delivery system (SMEDDS): development and optimization. AAPS PharmSciTech. 2008;9(2):628–634. https://doi.org/10.1208/s12249-008-9080-6.
18. Riehm DA, Rokke DJ, Paul PG, Lee HS, Vizanko BS, McCormick AV. Dispersion of oil into water using lecithin-Tween 80 blends: the role

of spontaneous emulsification. J Colloid Interface Sci. 2017;487:52–59. https://doi.org/10.1016/j.jcis.2016.10.010.

19. Tarivitla LP, Reddy MS. Characterization of Self-Emulsifying Drug Delivery Systems (SEDDS). Int J. Res Pub Rev. 2024;5(8):3403–3408.
20. Srinivas M, Kundarapu S, Srilalitha G, Sharma JVC. Design and Characterization of Self Emulsifying Drug Delivery System of Repaglinide. Intl J Pharm Sci Rev Res. 2014;25(1):41–46.
21. Aggarwal G, Harikumar SL, Jaiswal P, Singh K. Development of self-microemulsifying drug delivery system and solid-self-microemulsifying drug delivery system of telmisartan. Int J Pharm Investig. 2014;4(4):195–206. https://doi.org/10.4103/2230-973X.143123.
22. Obranović M, Bryś J, Repajić M, Balbino S, Škevin D, Bryś A, Tonković P, Medved AM, Uzelac VD, Kraljić K. Fatty Acid and Sterol Profile of Nutmeg (Myristica fragrans) and Star Anise (Illicium verum) Extracted Using Three Different Methods. Proceedings. 2020;70(1):33. https://doi.org/10.3390/foods_2020-07687.
23. Dokania S, Joshi AK. Self-micro emulsifying drug delivery system (SMEDDS) – challenges and road ahead. Drug Deliv. 2015;22(6):675–690. https://doi.org/10.3109/10717544.2014.896058.
24. Patel AR, Vavia PR. Preparation and in vivo evaluation of SMEDDS (Self-Microemulsifying Drug Delivery System) containing fenofibrate. AAPS J. 2007;9(3):41. https://doi.org/10.1208/aapsj0903041.
25. Kunwarpuriya AS, Khutle NM, Raval AJ, Doke VV. Formulation and Evaluation of Self-Microemulsifying Drug Delivery System of Fluvastatin Sodium. J Pharm Sci Bioscientific Res. 2020;10(1):120–133.
26. Jeevana JB, Sreelakshmi K. Design and evaluation of self-nanoemulsifying drug delivery system of flutamide. J Young Pharm. 2011;3(1):4–8. https://doi.org/10.4103/0975-1483.76413.
27. Parmar S, Puri R. Self-Emulsifying Drug Delivery System: A Technique to Improve Oral Bioavailability of Poorly Soluble Drugs. Intl J. Pharma Res. 2021;13(3):764–772. https://doi.org/10.31838/ijpr/2021.13.03.120.
28. Nipun TS, Ashraful Islam SM. SEDDS of gliclazide: preparation and characterization by in-vitro, ex-vivo and in-vivo techniques. Saudi Pharm J. 2014;22(4):343–348. https://doi.org/10.1016/j.jsps.2013.06.001.
29. Singh V, Saleem MA, Khalid SK, Pange S, Ahnaf O. Study on In-vitro permeation enhancement of Ketoprofen by formation of solid dispersion. Intl Res J Pharm. 2011;2(24):134–140.
30. Mudrika K, Badarinath AV. Development and Evaluation of Mucoadhesive Flunarizine Nanoemulsion for Nose-To-Brain Drug Delivery in the management of Alzheimer's disease. J. Innov. Appl. Pharm Sci. 2026;11(1):22–26. https://doi.org/10.37022/jiaps.v11i1.816.