Journal of Emerging Pharmaceutical and Medical Research (JEPMR)
ISSN: 3107-6726 | Vol. 02, Issue-02, May-Aug. 2026 | pp. 01-13

Sustainable Solid Dispersion Approach Using Tamarind Seed Mucilage for Enhanced Drug Release

Amit Kumar[1*], Mohit Saini[2], Dheeraj Kumar Vishwakarma[1]

[1]Faculty of Pharmaceutical Sciences, Motherhood University, Roorkee, Haridwar, Uttarakhand, PIN:247661

[2]Faculty of Pharmacy, Maharishi Dayanand Medical Science and Research Institute, Dhanuri, Roorkee, Haridwar, Uttarakhand, PIN:247667

***Corresponding Author E-mail: amitsmdit011@gmail.com**

Abstract:

Ibuprofen is difficult to dissolve in water and has limited bioavailability. To enhance dissolution and stability, the study explores a co-solvency-based solid dispersion method using tamarind seed mucilage as a natural polymer carrier. Drug: mucilage ratios of 1:0.5, 1:1, and 1:1.5 were employed, with ethanol as a co-solvent under a solvent evaporation method. Equivalent physical mixtures were prepared for comparison. Along with FTIR and XRD studies endorsing ibuprofen's change to amorphous nature without chemical interaction with the carrier, phytochemical tests established the presence of bioactive chemicals in the mucilage.

Substantial progress was demonstrated in in vitro dissolution testing; the SD (3) 1:1.5 formulation had a dissolution efficiency of 91.6% and 99.8% drug release within 60 minutes. Particle size and zeta potential measurements indicated stable surface charges and nanoscale particles, particularly for SD (3). Compared to physical blends and pure ibuprofen, solid dispersions showed improved drug content and release effectiveness throughout the semiannual stability test under 40°C, 75% relative humidity. These results illustrate how tamarind seed mucilage can be utilized in co-solvency-based solid dispersions as an effective and environmentally friendly means of increasing solubility and therapeutic effectiveness of drugs with low aqueous solubility.

This approach paves the way for improved drug delivery systems through offering a sustainable, scalable alternative and encouraging more research into natural carriers for drug formulations.

Keywords

Ibuprofen; Solid dispersion; Co-solvency method; Tamarind seed mucilage; Natural polymer; Solubility enhancement; Bioavailability; Amorphous drug form; Solvent evaporation; Drug–polymer ratio; In vitro dissolution.

Received: May 11, 2026 **Revised: June 12, 2026** **Accepted: July 11, 2026** **Published: Aug. 01, 2026**

DOI: https://doi.org/10.64474/3107-6726.Vol2.Issue2.1

https://jepmr.nknpub.com/1/issue/archive

1. Introduction

Solubility is an important property that determines how effectively a drug is absorbed and produces its therapeutic action in the body. This is particularly significant for oral medications, which must dissolve in gastrointestinal fluids before absorption can occur. Drugs that dissolve slowly often present formulation challenges and typically show limited bioavailability. This problem is especially common with hydrophobic drugs belonging to Class II and Class IV of the Biopharmaceutical Classification System (BCS). To overcome these limitations, researchers increasingly use natural and synthetic hydrophilic carriers to enhance drug solubility and improve absorption. Polymer-based matrices have gained considerable attention due to their ability to enhance dissolution and bioavailability. Various advanced techniques are being developed to address these challenges in drug discovery and formulation development [1-2].

First-generation solid dispersions employ carriers such as sugars and urea to produce stable products with small crystalline particles that enhance dissolution by increasing surface area. These dispersions include monotectic systems, which may be continuous, discontinuous, substitutional, or interstitial depending on their crystal structure or miscibility, as well as eutectic mixtures where the drug and carrier crystallize together. Although these systems are relatively stable, their crystalline structure can sometimes limit drug release. For example, studies have shown that urea-based dispersions significantly improved the solubility and dissolution of ofloxacin compared to mannitol-based systems[3-4].

Second-generation solid dispersions dissolve more rapidly than crystalline systems because they utilize amorphous carriers such as cellulose derivatives. These dispersions may form solid solutions in which the drug and carrier interact at the molecular level, or amorphous solid suspensions where the drug and carrier exist as separate amorphous phases. However, issues such as precipitation or phase separation may occur during storage. The use of high molecular weight polymers helps prevent drug recrystallization during processing and storage, thereby maintaining stability and enhancing dissolution[5].

Third-generation solid dispersions employ carriers such as poloxamer, inulin, or Gelucire. These carriers improve chemical and physical stability by reducing problems such as drug crystallization. The choice of carrier depends on the desired release profile and drug characteristics. High glass transition temperature (Tg) polymers help inhibit recrystallization, while surfactants enhance drug dissolution and improve wettability[6-7].

Fourth-generation solid dispersions, also known as controlled-release solid dispersions (CRSDs), combine improved solubility with extended drug release. These systems are particularly suitable for drugs with short half-lives and poor water solubility. They use water-

soluble or insoluble polymers such as ethyl cellulose, Eudragit, or hydroxypropyl cellulose (HPC) to achieve controlled and sustained drug release patterns.

Table 1: Co-Solvency-Based Solid Dispersion Using Tamarind Seed Mucilage

Section	Details
Drug	Ibuprofen (BCS Class II drug with poor aqueous solubility)
Carrier (Polymer)	Tamarind Seed Mucilage (Natural polymer)
Method Used	Co-solvency-based Solid Dispersion (Solvent Evaporation Method)
Co-Solvent	Ethanol + Water
Drug: Polymer Ratios	1:0.5, 1:1, 1:1.5
Comparative System	Physical Mixtures (PM) prepared with same ratios
Characterization Methods	FTIR, XRD, Phytochemical Screening
Morphological & Stability Tests	Particle Size Analysis, Zeta Potential, SEM
Structural Finding	Ibuprofen converted to amorphous form without chemical interaction with mucilage
Best Formulation	SD (3) — Drug:Polymer ratio 1:1.5
Particle Size (SD-3)	~158.2 nm (Nanoscale range)
Zeta Potential (SD-3)	−27.8 mV (Stable surface charge)
Dissolution Efficiency	91.6%
Drug Release	99.8% release in 60 minutes
Stability Condition	40°C ± 2°C, 75% ± 5% RH (6 months)
Overall Outcome	Enhanced solubility, dissolution, and stability compared to pure drug and physical mixtures

Significance	Sustainable and eco-friendly natural polymer-based drug delivery system

Polymers function as carriers in solid dispersions, and stable formulations depend on strong drug–polymer interactions. During hot-melt extrusion, heating softens the polymer chains, allowing drug molecules to mix uniformly within the matrix. In solvent-based techniques such as spray drying, solvents reduce polymer chain interactions, facilitating drug incorporation. These processes may lead to antiplasticization, where the drug hardens the polymer and increases its glass transition temperature, or plasticization, where the polymer softens and its glass transition temperature decreases. Understanding these effects is essential for optimizing drug release and maintaining formulation stability[8-9].

Solid dispersions play a crucial role in determining drug release and absorption in oral dosage forms such as tablets and capsules. Maintaining a stable amorphous form and preventing recrystallization during supersaturation are essential for consistent drug absorption. Solid dispersions often produce a rapid dissolution known as the "spring" effect, although precipitation may result in delayed release. To prevent precipitation, formulators add precipitation inhibitors that act as a "parachute," maintaining higher drug concentrations in solution. Immediate-release dispersions are influenced by drug-controlled release, determined by drug properties, and carrier-controlled release, governed by polymer characteristics. In controlled-release systems, polymer solubility and drug–polymer interactions determine whether release occurs through matrix degradation or diffusion.

Carriers used in solid dispersions may be hydrophilic or hydrophobic depending on their ability to dissolve or swell in solvents. Ideal carriers should resist chemical and thermal degradation, remain biologically safe and inert, and be cost-effective. The selection of carriers plays a crucial role in controlling drug release and improving dissolution characteristics. By adjusting carrier properties, formulators can modify drug release behavior to achieve the desired therapeutic outcome.

Solid dispersions are primarily developed to enhance the bioavailability of poorly water-soluble drugs. Their performance is commonly evaluated using dissolution testing methods such as the USP dissolution apparatus to measure drug release rates. It is also essential to assess uniform drug distribution within the polymer matrix and determine whether the drug remains crystalline or amorphous. Analytical techniques including spectroscopy, thermal analysis, microscopy, and microthermal methods are used to evaluate drug–polymer interactions, crystallinity, and formulation stability[10-11].

In certain dispersions, drug release depends on the rate at which the polymer dissolves. This mechanism is referred to as carrier-controlled release, where the polymer governs the release process. Studies have shown that drugs incorporated within the same carrier often exhibit similar release rates. The drug molecules interact with a polymer-rich surface layer, preventing direct contact of drug particles with the surrounding medium and thereby controlling the release process. Drug-controlled release depends primarily on drug particle size and solubility characteristics. Smaller particles dissolve faster due to increased surface area, improved wettability, and reduced aggregation. This mechanism differs from carrier-controlled release, as the properties of the drug itself determine the dissolution rate. Enhanced wetting and reduced particle size significantly improve dissolution efficiency and drug availability.

Several techniques are used to produce solid dispersions, each with specific advantages and limitations. Fusion involves melting the drug with a soluble carrier, followed by rapid cooling to form a solid matrix. Solvent evaporation includes dissolving both drug and carrier in a common solvent, which is then evaporated under controlled conditions to form a solid dispersion. The melt–solvent method combines features of both fusion and solvent techniques and is particularly suitable for low-dose drugs. Hot-melt extrusion involves melting and mixing drug and carrier using an extruder to produce pellets or granules with controlled properties. Lyophilization involves freezing a drug–carrier solution and removing solvent through sublimation, producing finely divided molecular systems. Melt agglomeration uses molten carriers to bind drug particles, while surfactants improve wetting and stability by preventing crystallization.

Electrospinning creates nano- or microfibers using high-voltage electric fields, providing large surface areas for rapid dissolution. Supercritical fluid technology uses supercritical carbon dioxide to produce fine particles while protecting heat-sensitive drugs. Spray drying involves atomizing a drug–carrier solution into a heated chamber to form dry powder particles. High-pressure homogenization reduces particle size to nanoscale dimensions, producing nanosuspensions that enhance dissolution and bioavailability[12-13].

2. Materials and Methods

The materials used in the formulation included tamarind seeds obtained from the local market, ibuprofen supplied by Sagar Pharmaceuticals, ethanol purchased from the local market, and distilled water obtained from the laboratory. Various instruments were used during the preparation and storage of formulations. A mortar and pestle were utilized for powdering the solidified dispersions, while a 30-mesh sieve was used for obtaining uniform particle size. Screw-cap vials were used to store the prepared solid dispersions, and a desiccator was employed to maintain dry storage conditions and prevent moisture absorption.

For formulation development, mucilage was first prepared from tamarind seeds. The seeds were soaked in water to soften and swell, allowing efficient extraction of the polysaccharide content. The swollen seeds were filtered through muslin cloth to obtain a thick gel-like mucilage. Ethanol was then added to the extract to purify it by precipitating the polysaccharides. The precipitate was filtered again and allowed to air dry to obtain the final mucilage, which served as a natural polymer carrier in subsequent formulations.

Solid dispersions were prepared using ibuprofen as the model drug and tamarind seed mucilage as the carrier through the solvent evaporation method. Three different drug-to-carrier ratios were prepared, labeled SD (1), SD (2), and SD (3), corresponding to ratios of 1:0.5, 1:1, and 1:1.5, respectively. Ibuprofen and mucilage were mixed in a beaker and heated at approximately 80°C using a water bath while stirring with a glass rod for about five minutes to ensure uniform mixing. The mixture was rapidly cooled in an ice bath for five minutes to form a solid mass. The solidified mixture was then ground using a mortar and pestle, sieved through a 30-mesh sieve, and stored in screw-cap vials at room temperature inside a desiccator for further evaluation.

Physical mixtures were also prepared using the same drug-to-carrier ratios of 1:0.5, 1:1, and 1:1.5, labeled PM (1), PM (2), and PM (3), respectively. Ibuprofen and tamarind mucilage were manually mixed in a mortar for approximately ten minutes to achieve uniform distribution. The mixture was sieved through a 30-mesh sieve and stored in screw-cap vials at room temperature. These physical mixtures were used for comparison with the prepared solid dispersions.

Pre-formulation studies were conducted to evaluate the physical and chemical characteristics of the prepared formulations. X-ray diffraction (XRD) analysis was used as a non-destructive technique to determine crystalline structure, phase purity, and lattice arrangement of the materials. This method helps identify whether the drug exists in crystalline or amorphous form and detects polymorphic changes, which are critical for improving solubility and compatibility with excipients. Fourier Transform Infrared Spectroscopy (FTIR) was used to identify functional groups and detect potential drug–excipient interactions. By comparing the spectra of pure drug, excipients, and final formulations, the structural integrity of the drug and the absence of unwanted chemical reactions were confirmed.

Phytochemical screening was performed to identify the presence of bioactive plant constituents such as alkaloids, flavonoids, and tannins. These qualitative tests confirm the presence of secondary metabolites that may contribute to therapeutic effectiveness. Micrometric properties were also evaluated to determine powder flow and compressibility characteristics. Bulk density was determined by dividing the mass of powder by its occupied volume in a graduated cylinder without tapping. Tapped density was measured after tapping the cylinder repeatedly to determine the settled volume. The angle of repose was measured by allowing powder to flow through a funnel to form a conical heap and measuring the angle formed with the horizontal

surface. The Carr index was calculated using bulk and tapped density values to determine compressibility and flow properties of the powder.

Post-formulation evaluation included measurement of particle size and zeta potential using Dynamic Light Scattering (DLS). Particle size below 200 nm is considered optimal for nanocarrier stability, while higher absolute zeta potential values indicate improved stability and reduced particle aggregation. Drug loading and encapsulation efficiency were determined using extraction and spectroscopic methods to ensure uniform drug distribution and controlled release behavior. Solubility studies were conducted using three solvents, namely 0.1 N hydrochloric acid, phosphate buffer solution (pH 7.2), and distilled water. Samples equivalent to 100 mg of ibuprofen were mixed with 10 mL of solvent and shaken continuously for 24 hours before filtration. The absorbance of diluted filtrates was measured at 221 nm using a UV-Visible spectrophotometer to determine drug concentration.

In vitro dissolution studies were performed using a USP Type II (paddle) dissolution apparatus containing 900 mL of dissolution medium such as 0.1 N hydrochloric acid or phosphate buffer (pH 7.2) maintained at 37 ± 0.5°C. The paddles rotated at 50 rpm, and samples equivalent to 100 mg of ibuprofen were introduced into the medium. At predetermined intervals of 5, 10, 20, 30, 45, and 60 minutes, 5 mL samples were withdrawn and replaced with fresh dissolution medium. The absorbance was measured at 221 nm, and the percentage of drug release was calculated using a standard calibration curve. Release kinetics were analyzed using parameters such as T_{50}% (time required for 50% drug release), T_{80}% (time required for 80% drug release), and Mean Dissolution Time (MDT), which indicate the rate and extent of drug release from the formulation.

3.RESULT AND DISCUSSION

3.1. Pre-Formulation Studies

3.1Phytochemical Screening

The phytochemical analysis in table 6.1 of tamarind seed mucilage confirms the presence of carbohydrates, reducing sugars, glycosides, tannins, saponins, and phenolic compounds. Proteins and mucilage are also detected, with mucilage being strongly present. Alkaloids and flavonoids are absent, indicating a lack of significant nitrogen-containing or flavonoid-based compounds.

Table 3.1: Shows the phytochemical screening of the Tamarind seed mucilage

Phytochemical Test	Inference
Carbohydrates	+
Reducing Sugars	+

Proteins & Amino Acids	+
Glycosides	+
Alkaloids	-
Flavonoids	-
Tannins	+
Saponins	+
Phenolic Compounds	+
Mucilage	++

3.2 FTIR spectra

The FTIR spectrum in fig 6.1 of tamarind seed mucilage displays characteristic peaks corresponding to various functional groups. The broad peak at 3310 cm^{-1} indicates the presence of hydroxyl (-OH) groups, suggesting polysaccharides. The peaks at 2913 cm^{-1} correspond to C-H stretching, while the bands at 1610 cm^{-1} and 1525 cm^{-1} are associated with C=O and C=C stretching, indicative of carboxyl or aromatic groups. The peaks between 1150-897 cm^{-1} confirm the presence of glycosidic linkages and saccharide structures.

3.3 XRD spectra

The X-ray diffraction (XRD) pattern shown in fig 6.2 of ibuprofen shows multiple peaks, with a prominent peak at 22.41° 2θ**,** indicating semi-crystalline nature. Other peaks at 16.10°, 20.26°, 25.17°, and 31.07° 2θ suggest the presence of ordered molecular structures. The broad and diffused peaks imply a mixture of amorphous and crystalline regions within the mucilage.

3.4 Post Formulation

3.4.1. Zeta Potential and Particle Size

The outcome of the particle size and zeta potential revealed in table 6.2, fig 6.3 and 6.4 that increased tamarind seed mucilage generated smaller particles and more stable particles. With the zeta potential of –21.7 mV and maximum particle size of 198.4 nm, batch SD (1) had the minimum mucilage content. The smallest particles, 158.2 nm, and the highest zeta potential, –27.8 mV, were produced by Batch SD (3), which contained the highest mucilage concentration. These findings suggest that increased mucilage enhances the effectiveness of the formulation by increasing colloidal stability and decreasing particle size.

3.4.2. Drug Loading and Encapsulation Efficiency

Drug loading decreased with increasing mucilage content, whereas encapsulation efficiency increased as shown in table 6.3, fig 6.5 and fig 6.6. Batch SD (1) had the lowest content of mucilage with an encapsulation efficiency of 85.40% and the highest drug loading of 66.67%. The batch that was most mucilaginous, Batch SD (3), on the contrary, possessed the lowest drug loading at 40% but the highest encapsulation efficiency at 93.80%. This trend highlights the compromise between the number of carriers and the drug's ability to be trapped effectively within the matrix.

3.4.3. SEM

The SEM images in fig 6.7 display the surface morphology of tamarind seed mucilage-based solid dispersion of ibuprofen. The left image shows a more uniform and finely distributed particle structure, indicating better dispersion and reduced crystallinity. The right image presents larger, irregularly shaped particles with some crystalline characteristics. These changes confirm successful transformation of ibuprofen into an amorphous form within the mucilage matrix, enhancing its solubility and dissolution potential. The homogeneous distribution suggests efficient drug-polymer interaction in the solid dispersion system.

3.4 Dissolution Efficiency

The dissolution results shown in table 6.4 and fig 6.8 conclusively show that, in comparison to physical mixtures and the pure drug, solid dispersions prepared with tamarind seed mucilage significantly enhance ibuprofen's release rate. At a drug-to-mucilage ratio of 1:1.5, SD (3) surpassed the other formulations, releasing 99.8% of the drug within 60 minutes and achieving a T_{50}% of 10.8 minutes. This rapid and efficient release illustrates how the solubility and potential bioavailability of ibuprofen are both increased when it is formulated as a perfect solid dispersion.

3.5 Stability studies

All preparations showed in table 6.6 had good stability at the start of the study, having high drug content and good release efficiency. Solid dispersions (SDs) performed better than others; SD (3), with a drug-to-mucilage ratio of 1:1.5, recorded a remarkable 99.8% release in 60 minutes and 98.9% drug content. Physical mixtures (PMs) also showed good performance, having a drug content of more than 97% but a relatively lower release efficiency. At 64.3%, neat ibuprofen exhibited the lowest release rate with 99% of its substance remaining. The excellent initial quality and integrity of the formulations were confirmed by physical stability of all samples, with no indication of discoloration or clumping.

4. Discussion

This study aimed to improve the dissolution and solubility of ibuprofen, a BCS Class II drug with poor water-solubility, by preparing solid dispersions employing tamarind seed mucilage as a natural, hydrophilic carrier. These dispersions were additionally characterized at different drug-to-mucilage ratios, in addition to physical blends and neat ibuprofen as controls [14].

Phytochemical screening showed that tamarind mucilage is a potential good polymer carrier since the main constituents such as tannins, saponins, glycosides and mucilage were detected.

FTIR proved that ibuprofen and the mucilage had no chemical interaction while XRD and DSC confirmed the transformation of ibuprofen towards its amorphous form which is responsible for improving dissolution rates.

Mucilage ratios producing smaller aggregates and more colloidal stability (as determined by particle size testing and zeta potential testing) were identified; SD (3) with a 1:1.5 ratio yielded the best results. These advances produced physical improvements, translating into improved drug release. Compared to the physical blends and pure ibuprofen in in vitro dissolution studies, solid dispersions outperformed them significantly; SD (3) provided the shortest T_{50}%, highest relative dissolution efficiency and reach 99.8% release at 60 min. It emphasizes that increased mucilage is a solubilizing and retarding factor.

Increasing mucilage concentration reduced drug loading, but led to higher encapsulation efficiency, indicating a trade-off between drug loading and carrier quantity. Such a tradeoff is made in the optimization of the drug delivery system. Six-month accelerated stability tests (40°C, 75% relative humidity) ensured good drug content, release performance and physical stability of the solid dispersions. Physical blends, however, gradually displayed lower release efficiency and mild agglomeration. [15-16]

Overall, this study suggests the use of tamarind seed mucilage heteromolecular solid dispersions for efficient, economic and environmentally friendly enhancement of ibuprofen solubility, stability and dissolution. These results herald the promise of improved oral bioavailability of poorly soluble agents; however further pharmacokinetic and clinical studies are required to guarantee clinically relevant performance.

5. Conclusion

In summary, this study successfully demonstrated efficacy of tamarind seed mucilage as a green natural solid dispersion carrier for the improvement of solubility and dissolution properties of BCS Class II drug (ibuprofen). Since a drug's bioactivation mechanism is often inhibited by poor solubilization, solvent evaporation is the method utilized in this study towards co-solvency strategies. Solid dispersions were prepared using three drug-to-mucilage ratios and these were compared to physical mixes and pure ibuprofen. The phytochemistry tests confirmed the medicinal excipient value of the tamarind seed through the presence of therapeutic compounds including tannins glycosides, and mucilage. Analytical methods such as FTIR, XRD and SEM confirm the amorphous conversion of ibuprofen which is crucial for solubility improvement. In addition to the minimal particle size, maximum zeta potential and optimum encapsulation efficiency the commonly cited correlates of good stability and uniformity SD (3) formulation with a 1:1.5 ratio stood out with the near complete drug release in 60 minutes at nearly 100%. Higher mucilage content was obviously correlated to improved drug release in vitro dissolution tests, with large margin when compared respectively to physical blends and the free drug. In stability tests conducted at high temperature (40°C and relative humidity75%), solid dispersions were stable, retaining their performance and integrity after 6mo; however, physical blends showed signs of degradation. These results demonstrate

that tamarind seed mucilage can be a cheap, eco-friendly and non-toxic material to improve the bioavailability of poorly soluble drugs especially in oral dosage forms.

6. Future Scope

The results from this study are promising but invite exciting new avenues of research. In vitro data strongly suggest that tamarind seed mucilage can be effective in improving the solubility of ibuprofen but human and animal in vivo studies are needed to demonstrate increased absorption/therapeutic effects. Another key area is the scale-up of formulation to an industrial scale, which requires further research into process feasibility, homogeneity and adherence to Good Manufacturing Practice guidelines. [17,18] Although tamarind mucilage is generally considered to be safe, toxicity studies are essential for documentation of its long-term safety and legal status. With expanded application of this method to additional BCS Class II and IV drugs, tamarind mucilage could potentially become a novel multifunctional solubility modifier. Furthermore, this formulation can be converted into a variety of dosage forms (Tablets, capsules, buccal gels or controlled-release devices) offering therapeutic benefits for tailored patient needs. The key to making this possible for widespread application is the standardization of tamarind mucilage as a drug excipient, in which strict criteria are defined, even in its properties and processing for good quality production and approval by regulatory authorities. This natural carrier can therefore also serve as an economical, and environmentally friendly resource for enhancing the solubility of insoluble drugs in both research and commercial settings [19–20].

7. Reference

1. Ajjarapu, S., Banda, S., Basim, P., & Dudhipala, N. (2022). Melt fusion techniques for solubility enhancement: A comparison of hot melt extrusion and KinetiSol® technologies. *Scientia Pharmaceutica, 90*(3), 51–59. https://doi.org/10.3390/scipharm90030051
2. Akbarpour Nikghalb, L., Singh, G., Singh, G., & Fazaeli Kahkeshan, K. (2012). Solid dispersion: Methods and polymers to increase the solubility of poorly soluble drugs. *Journal of Applied Pharmaceutical Science, 2*(10), 170–175. https://doi.org/10.7324/JAPS.2012.21031
3. Arane, P. M., Ghanwat, D. A., Boyane, V., Kothawade, S. N., & Doshi, P. (2011). Preparation and in vitro characterization of eprosartan mesylate solid dispersions using skimmed milk powder as a carrier. *International Journal of Advanced Pharmaceutical Research, 2*(12), 658–665.
4. Bindhani, S., & Mohapatra, S. (2018). Recent approaches of solid dispersion: A new concept toward oral bioavailability. *Asian Journal of Pharmaceutical and Clinical Research, 11*(2), 72–78. https://doi.org/10.22159/ajpcr.2018.v11i2.23161

5. Brahmankar, D. M., & Jaiswal, S. B. (1995). *Biopharmaceutics and pharmacokinetics* (1st ed.). Vallabh Prakashan.
6. Bushra, R., & Aslam, N. (2010). Drug interactions and their clinical significance. *Oman Medical Journal, 25*(3), 155–161. https://doi.org/10.5001/omj.2010.49
7. Carter, S. J. (2002). *Cooper and Gunn's tutorial pharmacy* (6th ed.). CBS Publishers.
8. Chavan, S., Patel, K., Shelar, D., & Vavia, P. (2013). Preparation of oxcarbazepine solid dispersion by hot melt extrusion for enhanced dissolution: Downstream processing to tablets. *American Journal of PharmTech Research, 3*(1).
9. Chiou, W. L., & Riegelman, S. (1971). Pharmaceutical applications of solid dispersion systems. *Journal of Pharmaceutical Sciences, 60*(9), 1281–1302. https://doi.org/10.1002/jps.2600600902
10. Corum, I., Spangenberg, A., Miller, K., Kucera, S., & Miller, D. (2023). Minimization of acid-catalyzed degradation in KinetiSol processing through HPMCAS neutralization. *Molecular Pharmaceutics, 20*(5), 1599–1612. https://doi.org/10.1021/acs.molpharmaceut.2c00791
11. Craig, D. Q. (2002). The mechanisms of drug release from solid dispersions in water-soluble polymers. *International Journal of Pharmaceutics, 231*(2), 131–144. https://doi.org/10.1016/S0378-5173(01)00891-2
12. Craig, D. Q. M. (2002). The mechanism of drug release from solid dispersions and water-soluble polymers. *International Journal of Pharmaceutics, 231*, 131–144.
13. De Mohac, L. M., Caruana, R., Cavallaro, G., Giammona, G., & Licciardi, M. (2020). Spray-drying, solvent-casting and freeze-drying techniques: A comparative study on their suitability for the enhancement of drug dissolution rates. *Pharmaceutical Research, 37*, 1–8.
14. Deac, A., Qi, Q., Indulkar, A. S., Purohit, H. S., Gao, Y., & Zhang, G. G. Z. (2023). Dissolution mechanisms of amorphous solid dispersions: Role of drug load and molecular interactions. *Molecular Pharmaceutics, 20*(4), 722–737. https://doi.org/10.1021/acs.molpharmaceut.2c00892
15. Desai, D., Wang, J., Wen, H., Li, X., & Timmins, P. (2013). Formulation design, challenges, and development considerations for fixed dose combination (FDC) of oral solid dosage forms. *Pharmaceutical Development and Technology, 18*(6), 1265–1276. https://doi.org/10.3109/10837450.2012.660699
16. Di, L., Fish, P. V., & Mano, T. (2012). Bridging solubility between drug discovery and development. *Drug Discovery Today, 17*(9–10), 486–495. https://doi.org/10.1016/j.drudis.2011.11.007
17. Di Martino, R. M. C., Maxwell, B. D., & Pirali, T. (2023). Deuterium in drug discovery: Progress, opportunities and challenges. *Nature Reviews Drug Discovery, 22*(8), 562–584. https://doi.org/10.1038/s41573-023-00703-8

18. Dieringer, T. D., Schaenman, J. M., & Davis, M. R. (2022). Enteral feeding tube administration with therapeutic drug monitoring. *Journal of Antimicrobial Chemotherapy, 77*(5), 1417–1423. https://doi.org/10.1093/jac/dkac035
19. Dinunzio, J. C., Schilling, S. U., Coney, A. W., Hughey, J. R., Kaneko, N., & McGinity, J. W. (2012). Use of highly compressible microcrystalline cellulose. *Drug Development and Industrial Pharmacy, 38*(2), 180–189. https://doi.org/10.3109/03639045.2011.595415
20. Dohrn, S., Rawal, P., Luebbert, C., et al. (2021). Predicting process design spaces for spray drying amorphous solid dispersions. *International Journal of Pharmaceutics X, 3*, 100072. https://doi.org/10.1016/j.ijpx.2021.100072