**Enhancement of Solubility and Dissolution of Piroxicam by Self Emulsifying Drug Delivery Technique**

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**ABSTRACT**

Self-emulsifying drug delivery systems (SEDDS) help to deliver lipophilic drugs with improved bioavailability. The objective of this study was to develop SEDDS to improve solubility and enhance the oral absorption of the poorly water soluble drug, piroxicam. The influence of the oil, surfactant and co-surfactant types on the drug solubility and their ratios on forming efficient and stable SEDDS were investigated by construction of Pseudo ternary phase diagrams. Formulations were characterized for thermodynamic stability studies, Self-emulsification, Viscosity, Droplet size, Zeta potential, Differential Scanning Calorimetry, *in vitro* drug release, Diffusion and Stability studies. The drug diffusion from the optimised formulation C1 was 98.18±0.84% while from the marketed piroxicam capsule was 95.13±2.98%. The developed piroxicam SEDDS formulation showed greater dissolution, and diffusion than the pure drug and marketed capsule. Release kinetics showed that the mechanism of drug release is super class-II, as it follows zero order release and fits with korsmeyer-peppas model.

Key words: SEDDS, Bioavailability, Lipophilic, Piroxicam, Diffusion, Thermodynamic stability, Release kinetics.

**INTRODUCTION**

The oral route is the most convenient for drug administration, offering significant therapeutic benefits and high patient compliance, particularly for chronic conditions [1]. Although some oral formulations have been developed, their low bioavailability remains a significant obstacle. This challenge complicates the design of delivery systems that can enhance pharmacokinetic profiles and therapeutic outcomes. Efforts are currently focused on addressing the issues of low oral bioavailability, which stem from factors such as poor drug solubility, limited permeation, and enzymatic degradation, all of which hinder effective drug delivery.

**Self-Emulsifying Drug Delivery System**

Self-emulsifying drug delivery systems (SEDDS) are mixtures of oil and surfactants, ideally isotropic, and sometimes containing cosolvents, which emulsify spontaneously to produce fine oil-in-water emulsions when introduced into aqueous phase under gentle agitation. Medium chain tri-glyceride oils and non-ionic surfactants—which are less toxic—have recently been used in the formulation of SEDDS. These systems create fine emulsions in the gastrointestinal tract after oral delivery. When compared to ready-to-use emulsions, SEDDS have easier manufacturing properties and a better physical and/or chemical stability profile over extended periods of storage. Therefore, SEDDS may increase the rate and extent of absorption and produce more consistent blood-time profiles for drugs that have poor water solubility and rate-limited dissolution.

Self-emulsifying drug delivery systems (SEDDS) encompass both self-microemulsifying drug delivery systems (SMEDDS) and self-nanoemulsifying drug delivery systems (SNEDDS). SMEDDS formulations produce transparent microemulsions with droplet sizes ranging from 100 to 250 nm, whereas SNEDDS create emulsions with globule sizes below 100 nm. Microemulsions are thermodynamically stable colloidal dispersions consisting of small spheroidal particles dispersed in an aqueous medium, maintaining equilibrium. In contrast, nanoemulsions are nonequilibrium colloidal dispersion systems that will spontaneously undergo coalescence of the dispersed droplets over time. [2]

**METHODS**

**DRUG-EXCIPIENTCOMPATIBILITY STUDIES:**

**Fourier Transform Infra Red Studies3 (Ftir):** FT-IR spectroscopy was used to ascertain the compatibility between drug and the excipients. Liquid cell method was used for analysis. FT-IR of drug was compared with FT-IR spectra of SEDDS.

**Differential Scanning Calorimetry4: (DSC)** The thermal characteristics of formulation was investigated using a differential scanning calorimeter (DSC Q200 v24.2 build 107, Central Analytical Facility Lab, Osmania University, Hyderabad). Samples were placed in a sealed aluminium pans before heating under a nitrogen flow at a heating rate of 10 C/min from 50C to 200C.

**CHARACTERIZATION METHODS:**

**Optical Microscopy5:** A drop of micro emulsion was placed on a glass slide and diluted. A cover slip was placed over it and examined under an ordinary microscope for vesicle size and shape, using a pre calibrated ocular eye piece micro meter under 45 X 10 and 100 X 10.

**Solubility Studies6:** An adequate number of each selected vehicle was placed in different screw-capped glass vials, to these vials, excess of the drug was added and mixed for 48hrs at 37°C and analysed for drug absorbance using UV visible Spectrophotometer.

**Construction of the ternary phase diagram:** Peanut oil, Tween 80, and PEG 400 were combined in nine different Smix ratios of 1:1, 1:2, 1:3, 1:4 1:5, 1:6, 1:7, 1:8, 1:9, titrated using water to obtain nano emulsion regions. Visual observations of the nano emulsion regions led to a classification of transparent with good flow: oil/ water

Nano emulsions as clear (C), Slightly clear (SC), Turbid(T) Slightly turbid(ST).

**Preparation of piroxicam self-emulsifying drug delivery system7 :** For the formulation development, the Smix ratio was chosen based on the area of nano emulsification from the phase diagrams. With six different Smix ratios, SEDDS formulations were made with Tween 80 as the surfactant and PEG 400 as the co-surfactant. To Piroxicam, the appropriate amount of peanut oil was added to a glass vial, the appropriate amount of cosurfactant and surfactant was then added to the vial, the mixture was vortexed.

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| Formulation codes | **A1** | **A2** | **A3** | **A4** | **A5** | **B1** | **B2** | **B3** | **B4** | **B5** | **C1** | **C2** | **C3** | **C4** | **C5** |
| **Piroxicam** | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **Smix ratio** |  |  | **1:2** |  |  |  |  | **1:3** |  |  |  |  | **1:4** |  |  |
| **Oil: Smix** | 1:1 | 1:2 | 1:3 | 1:4 | 1:5 | 1:1 | 1:2 | 1:3 | 1:4 | 1:5 | 1:1 | 1:2 | 1:3 | 1:4 | 1:5 |
| **Peanut oil** | 245 | 163.3 | 122.5 | 98 | 81 | 245 | 163.33 | 122.5 | 98 | 81.66 | 245 | 163.33 | 122.5 | 98 | 81.66 |
| **Tween 80** | 81.67 | 108.9 | 122.5 | 130.66 | 136.33 | 61.25 | 81.66 | 91.87 | 98 | 102.85 | 49 | 65.33 | 73.5 | 78.4 | 81.66 |
| **PEG 400** | 163.3 | 217.8 | 245 | 261.33 | 272.22 | 183.75 | 245.01 | 275.63 | 294.0 | 306.25 | 196 | 26.134 | 294 | 313.6 | 326.68 |

Table no.1: SEDDS formulations with their compositions

**CHARATERIZATION OF SOLID SEDDS:**

**THERMODYNAMIC STABILITY STUDIES8:** The physical stability of a lipid-based formulation can be compromised by drug precipitation or phase separation within the excipient matrix. This can negatively impact both the performance and the visual appearance of the formulation.

**Heating cooling cycle:** The study involves six cycles of storage between 4ºC and 45ºC, with each temperature maintained for at least 48 hours. Formulations that remain stable under these conditions are then subjected to a centrifugation test.

**Centrifugation:** Formulations are centrifuged at 3500 rpm for 30 minutes. Those that do not exhibit any phase separation are then subjected to the freeze-thaw stress test.

**Freeze thaw cycle:** Formulations are given 3 freeze-thaw cycles between -21ºC and 25ºC, with each temperature maintained for at least 48 hours.

**SELF EMULSIFICATION ASSESSMENT9 :** The self-emulsifying capabilities of SEDDS formulations were assessed visually, with emphasis on the clarity and apparent stability of the resulting emulsion. SEDDS were added to distilled water and swirled magnetically. The solution was then visually inspected for drug precipitation.

**DRUG PRECIPITATION ASSESSMENT10 :** After 24 hours of visual inspection, the resulting emulsion was evaluated for drug precipitation. The formulations were classified as clear (transparent), non-clear (turbid), stable (no precipitation after 24 hours), or unstable (precipitation within 24 hours).

**VISCOSITY DETERMINATION11:** SEDDS was diluted tenfold with distilled water in a beaker while being constantly stirred on a magnetic stirrer. The viscosity of the resulting microemulsion and initial SEDDS was determined using a Brookfield viscometer.

**DETERMINATION OF DROPLET SIZE AND ZETA POTENTIAL12:** Photon correlation spectroscopy (PCS), which studies fluctuations in light scattering owing to Brownian motion of the particles, was used to evaluate the droplet size and zeta potential of the produced emulsion using a Zetasizer ZS 90. Light scattering was measured at 25°C from a 90° angle.

### **DRUG CONTENT13:** SEDDS formulation equal to 25 mg of Piroxicam was taken, diluted in methanol, and the UV-visible spectrophotometer was used to measure the absorbance at 332 nm.

**DRUG RELEASE PROFILES OF SELECTED SEDDS14:** All the Selected formulations of the ratios 1:2, 1:3 and 1:4 are prepared and filled in capsules, and using dissolution medium as 0.1NHCL, and Dissolution apparatus type - II, at 100rpm. UV visible spectroscopy was used to analyze the release quantity.

### **EVALUATION OF ISOTROPIC NATURE15:** Emulsion was placed on a glass slide and viewed under a microscope with cross polarized light.

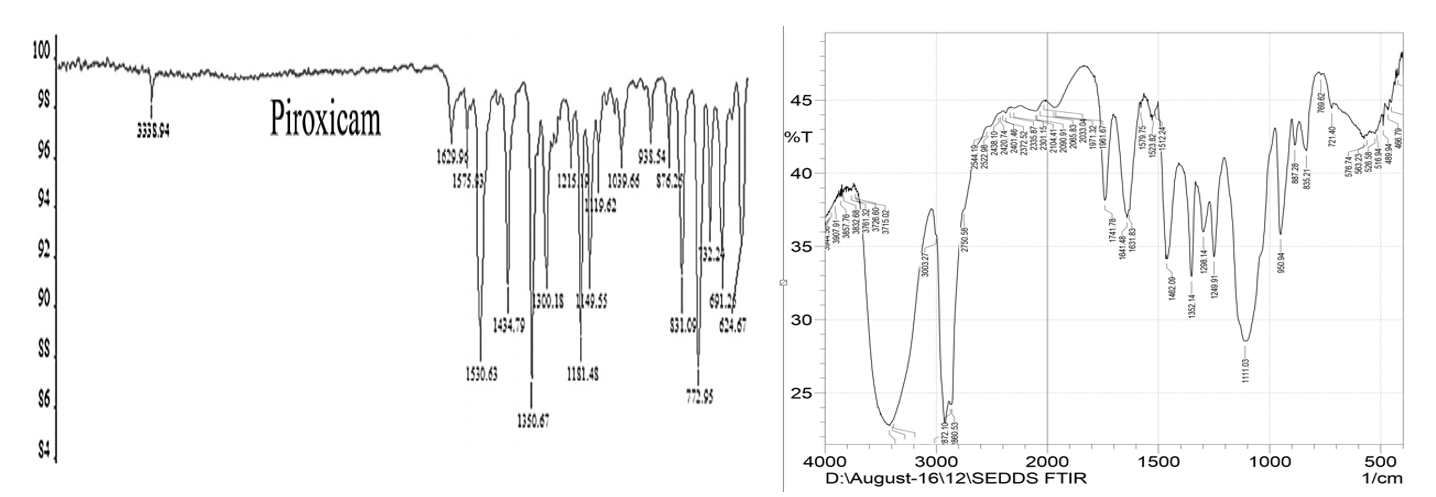
***In vitro* DIFFUSION STUDIES USING FRANZ DIFFUSION CELL16:** Using a Franz diffusion cell and a dialysis approach, the in vitro diffusion study of the piroxicam SEDDS was compared with a conventionally suspension. 0.1M HCl was used as dialyzing medium. The samples were examined using a UV-visible spectrophotometer set to 332 nm.

**STABILITY STUDIES18 :** In accordance with ICH, stability tests were conducted on the optimized SEDDS formulation at 40 °C/75% RH. They were taken out at regularly for analysis of drug release, emulsion globule size, drug precipitation assessment, and self-emulsification capacity.

**RESULTS AND DISCUSSION**

**DRUG-EXCIPIENT COMPATABILITY STUDIES:**

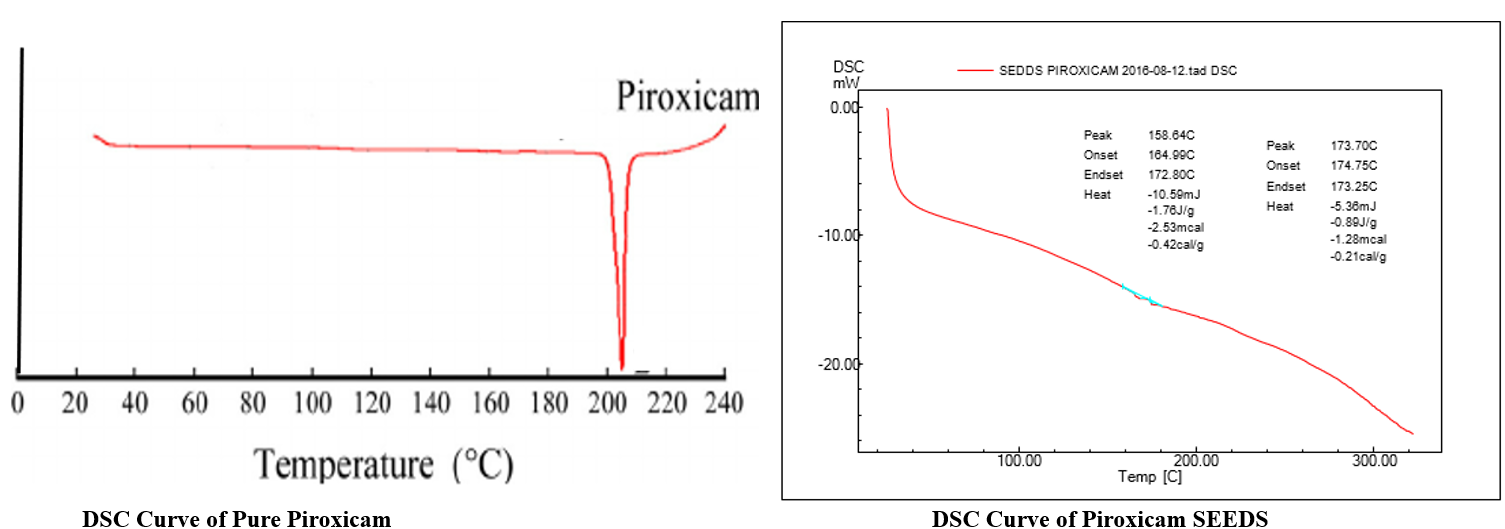
**Fourier Transform Infrared studies (FTIR): (Pure Piroxicam)**



**Fig.01. FTIR Spectra of Piroxicam SEDDS**

FTIR analysis shows that Piroxicam is compatible with the polymers used.

**Differential Scanning Calorimeter: (DSC)**

**Fig 02: DSC Curve of pure Piroxicam Fig 03: DSC Curve of Piroxicam SEEDS**

**PSEUDOTERNARY PHASE DIAGRAMS:** 

**Fig 04: Pseudo ternary phase diagrams of 1:2, 1:3 and 1:4 surfactant: co surfactant ratio**

Pseudo-ternary phase diagrams of formulations containing oil, surfactants, and co-surfactants dispersed in distilled water at 37 degrees Celsius. Surfactant = Tween 80, Co surfactant = PEG-400. The shadow area represents micro emulsion region.

Among the nine surfactant: Surfactant co-surfactant ratios of 1:2, 1:3,1:4 has larger micro emulsion region. As micro emulsion region in ternary phase diagram increases, self-emulsification efficiency increases. In contrast ratios 1:1, 1:5, 1:6, 1:7, 1:8, 1:9 showed a small micro emulsification region. So, depending on the results, ratios of 1:2, 1:3, and 1:4 were selected for further studies.

**THERMODYNAMIC STABILITY STUDIES:**

Formulations A1 - A5, B1 - B5 and C1 to C5 showed no signs of phase separation. But formulations A5, B3 and B4, C2, C3, C4 separates out into two phases

**Heating cooling cycle:** All the formulations were stable under heating cooling cycle. And hence further subjected to centrifugation test.

**Centrifugation:** Formulations A5, B3 and B4, C3, C4 separates out into two phases.

**Freeze thaw cycle:** Except formulations A5, B3 and B4, C2, C3, C4 all the remaining showed good stability with no phase separation, creaming, or cracking.

**SELF EMULSIFICATION AND PRECIPITATION:**

A1, A2, formed clear dispersion and did not show any drug precipitation and thus were considered as stable. Formulation A3, B1, B2, C1, C2 showed drug precipitation, B3, B4, C2, C3, C4 were unstable.

#### **VISCOSITY DETERMINATION:**

The viscosity of the formulation A1 was found to be 17.2cps, for A2-169cps, A3-16.5cps, A4-16.0cps, B1-17.0cps, B2-16.8cp, B3-16.3cps, and for C3-15.8cps.

**DETERMINATION OF DROPLET SIZE AND ZETA POTENTIAL:**

The globule size of the formulation B1 was found to be 204.0nm, and formulation B2 was found to be 205.3nm, whereas for formulation C1 was 191.5nm and formulation C2 as 203.0nm. The formulation C1 which has lesser globule size was selected to be fit for further studies.

Piroxicam SEDDS was diluted with distilled water, and the resulted zeta potential was found to be -28.7mV for formulation B1, -26.0mV for formulation B2, for C1 and C2 -33.0mV, -35.8mV,respectively.

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| **Fig 05 Globule size- Zeta potential of formulation (B1)** | **Fig 06 Globule size- Zeta potential of formulation (B2)** |
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| **Fig 07 Globule size- Zeta potential of formulation (C1)** | **Fig 08 Globule size- Zeta potential of formulation (C2)** |

#### **EVALUATION OF ISOTROPIC NATURE18:**

Formulations A1 to A3, B1 to B3, and C1 showed a dark field under cross-polarized light, indicating that they are all isotropic.

**DRUG RELEASE PROFILES OF SELECTED SEDDS:**

The in vitro drug release of 1:2, 1:3 and 1:4 optimized SEDDS formulations is shown in the figures 9-11. Formulation C1 has showed higher release.

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| **Fig 09 Drug release profiles of Formulation (1:2)** | **Fig 10 Drug release profiles of Formulation (1:3)** |

**Fig 11 Drug release profiles of Formulation (1:4)**

***In vitro* DIFFUSION STUDY USING FRANZ DIFFUSION CELL:**

C1 showed 98.18 ± 0.81% of drug diffusion, while marketed commercial capsule showed a release of 95.13±2.98%. The drug release from the piroxicam SEDDS was found to be significantly higher as compared to that of the marketed capsule.

**Fig 12 *In-vitro* Diffusion studies of Piroxicam SEDDS and Marketed drug.**

**STABILITY STUDIES**

The C1 SEDDS was to be found to form clear dispersion and there was no sign of drug precipitation or capsule leak during the stability studies. The formulation showed a drug release of 98.37±0.31 by the end of 3rd month.

**DRUG RELEASE KINETICS**

The mechanism and kinetics of drug release of piroxicam is determined by the application of Zero order, First order, Higuchi, and Korsmeyerr-peppas kinetics. Based on the correlation coefficient values for the various kinetic models the zero order kinetics has an r2 value of 0.448. The Higuchi model also shows r2 value of 0.739 hence the mechanism of drug release is Non- Fickian transport. Koresmeyer- Peppas model yields an r2 value of 0.836 and the ‘n’ value is 1.133 (n>1.0); hence the drug release follows case II transport.

The aim of the present study was to develop and characterize self

emulsifying drug delivery system of Ibuprofen using edible and

natural castor oil and nonionic surfactant Tween 80 and Span 20

in varying concentrations. Span 20 was used as co surfactant in the

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self emulsifying capsules.

**CONCLUSION**

The present research was aimed to develop and characterize self-emulsifying drug delivery system of Piroxicam. The components for SEDDS formulation were chosen based on solubility testing, the development of a pseudo-ternary phase diagram, and droplet size analysis. The optimal SEDDS formulation contained 9.56% peanut oil, 58.52% Tween-80 as a surfactant, and 29.27% PEG-400 as a co-surfactant, resulting in adequate drug loading, quick self-emulsification in aqueous conditions, and microemulsion-sized droplets. In- vitro dissolution test showed that the release rate of the self-emulsifying capsules increased as the globule size decreased. This shows that the developed SEDDS formulation resulted in the spontaneous production of a microemulsion with small droplet size, allowing for quicker drug release into the aqueous phase and increased permeability. From the results formulation(**C1**), was found to be optimized with 97.9±0.23% drug release. The developed piroxicam SEDDS formulation showed higher diffusion than the commercial capsule. The stability testing depicts that C1 formulation was stable for a period of 3M. Release kinetics elucidated the mechanism of drug release is super class-II, as it follows zero order release and fits with korsmeyer-peppas model. Thus an efficient SEDDS of piroxicam was developed with enhanced drug loading capacity and release, thus showing possible increase in bioavailability.

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