

“ Enhancement of Solubility of poorly water soluble drug by solid dispersion technique”

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ABSTRACT:

Atovaquone and Satrinidazole has poor solubility resulting in low oral absorption hence low oral bioavailability. Hence to improve the solubility of poorly Atovaquone and Satrinidazole, hydrophilic polymers were used to enhance the dissolution by solid dispersion technique. Polyethylene Glycol 4000 and PVP k30 used to enhance the dissolution of both the drug by Solubilisation. Many alternative techniques have been used to improve such bioavailability; this study thus employed the simple solid dispersion technique and incorporated excipients which can increase the bioavailability of these drugs directly enhancing the dissolution rate of the drug and indirectly by reducing particle size. The aim of present work is to enhance the dissolution of poorly water soluble drug by using solid dispersion technique. To improve the dissolution rate, by using the various concentration of carrier or matrix with drug and hence, improve the bioavailability of poorly water soluble drug by formulating solid dispersion. To enhance the solubility of poorly water soluble drug, by means of solubilising agent. In case of poorly water soluble drug, dissolution may be the rate limiting step in the process of absorption. In such case, we can improve their solubility and dissolution rate. To study the effect of surfactant on the solid dispersion of poorly water soluble drug.

Keywords: Solubilisation, solid dispersion, Polyethylene Glycol, bioavailability, dissolution rate etc.

INTRODUCTION:

Oral bioavailability of drugs depends on its solubility and/or dissolution rate, therefore major problems associated with these drugs was its very low solubility in biological fluids, which results into poor bioavailability after oral administration^{1,3,5}. A drug with poor aqueous solubility will typically exhibit dissolution rate limited absorption, and a drug with poor membrane permeability will typically exhibit permeation rate limited absorption⁶. Therefore, pharmaceutical researchers, focuses on two areas for improving the oral bioavailability of drugs include: (i) enhancing solubility and dissolution rate of poorly water-soluble drugs and (ii) enhancing permeability of poorly permeable drugs⁷. It has been estimated that 40% of new chemical entities currently being discovered are poorly water soluble^{8,9}. Unfortunately, many of these potential drugs are abandoned in the early stages of development due to the solubility problems. It is therefore important to realize the solubility problems of these drugs and methods for overcoming the solubility limitations are identified and applied commercially so that potential therapeutic benefits of these active Solid dispersion (SD) is one of such methods and involves a dispersion of one or more active ingredients in an inert carrier or matrix in solid state prepared by melting, dissolution in solvent or melting-solvent method^{2,11}. The formulation of drugs having low aqueous solubility using solid dispersion technology has been an active area of research since 1960¹². Among the various approaches to improve solubility, the solid dispersion (SD) technique has often proved to be the most successful in improving the dissolution and bioavailability of poorly soluble drugs because it is simple, economic, and advantageous¹³. Solid dispersion means a group of solid products consisting of at least two different components, generally a hydrophilic inert carrier or matrix and a hydrophobic drug. The carrier can be either crystalline or amorphous in nature. Most commonly used carriers for the preparation of SDs are different grade of polyethylene glycols (PEGs) and polyvinylpyrrolidone (PVPs), sugar etc.

1.1. Advantages of Solid Dispersion^{10,12}

1. Preparation of solid dispersions results in particles with reduced particle size and thus the surface area is improved and increased dissolution rate is attained. The ultimate result is improved bioavailability.
2. Wettability is improved during solid dispersion production. Improved wettability results in increased solubility. Here the carriers play the major role to improve the wettability of the particles.
3. Particles in solid dispersions have been found to have a higher degree of porosity. The increased porosity of solid dispersion particles accelerates the drug release profile. Increased porosity also depends on the carrier properties.
4. In solid dispersions drugs are presented as supersaturated solutions which are considered to be metastable polymorphic form. Thus presenting drugs in amorphous form increase the solubility of the particles.

5. Rapid dissolution rates that result in an increase in the rate and extent of the absorption of the drug, and a reduction in presystemic both can lead to the need for lower doses of the drug.

1.2. Disadvantages of Solid Dispersion¹²

1.2.1 The major disadvantages of solid dispersion are related to their instability. Several systems have shown changes in crystalline and a decrease in dissolution rate with aging. The crystallization of Ritonavir from the supersaturated solution in a solid dispersion system was responsible for the withdrawal of the Ritonavir capsule (Norvir, Abboft) from the market.

1.2.2 Moisture and temperature have more of a deteriorating effect on solid dispersions than on physical mixtures. Some solid dispersion may not lend them to easy handling because of tackiness

1.3. LIMITATIONS OF SOLID DISPERSIONS³

Although a great research interest in solid dispersion in the past four decades, the commercial utilization is very limited. Problems of solid dispersion involve

- 1) The physical and chemical stability of drugs and vehicles,
- 2) Method of preparation, Reproducibility of its physicochemical properties
- 3) Formulation of solid dispersion into dosage forms, and
- 4) Scale-up of manufacturing processes¹⁷.

1.4 Classification of Solid dispersion,

1.4.1. On the basis of carrier used

1.4.1.1. First generation

First generation solid dispersions were prepared using crystalline carriers such as urea and sugar, which were the first carriers to be employed in solid dispersion. They have the disadvantage of forming crystalline solid dispersion, which were thermodynamically more stable and did not release the drug as quickly as amorphous ones.

1.4.1.2. Second generation

Second generation solid dispersions include amorphous carriers instead of crystalline carriers which are usually polymers. These polymers include synthetic polymers such as povidone (PVP), polyethyleneglycols (PEG) and polymethacrylates as well as natural product based polymers such as hydroxypropylmethyl-cellulose (HPMC), ethyl cellulose, and hydroxypropylcellulose or starch derivatives like cyclodextrins.

1.4.1.3. Third generation

Recently, it has been shown that the dissolution profile can be improved if the carrier has surface activity or self emulsifying properties. Therefore, third generation solid dispersions appeared. The use of surfactant such as inulin, inutec SP1, compritol 888 ATO, and poloxamer 407 as carriers was shown to be effective in originating high polymorphic purity and enhanced

in vivo bioavailability⁶.

1.4.2. On the basis of solid state structure

1.4.2.1. Drug and polymer exhibiting immiscibility in fluid state
If a drug and polymer are immiscible in their fluid state, it is expected that they would not exhibit miscibility on solidification of the fluid mixture. Such systems may be regarded as similar to their corresponding physical mixtures and any enhancement in dissolution performance may be owing to modification in morphology of drug and/or polymer due to physical transformation (i.e.,

solid to liquid state and back), intimate drug-polymer mixing, and/or enhanced surface area. Formation of crystalline or amorphous solid dispersions can be biased by the rate of solidification of mixture and the rate of crystallization of drug and/or polymer⁹.

1.4.2.2. Drug and polymer exhibiting miscibility in fluid state

If the drug and polymer are miscible in their fluid state, then the mixture may or may not undergo phase separation during solidification, thereby influencing the structure of solid dispersion⁹.

1.4.2.3. Eutectic Mixtures

Eutectic mixture was first described as solid dispersions in 1961 by Sekiguchi & Obi. Eutectic mixtures are formed when the drug and polymer are miscible in their molten state, but on cooling, they crystallize as two distinct components with negligible miscibility. When a drug (A) and a carrier (B) are co-melted at their eutectic composition defined by point 'e', as shown schematically in

Figure 1, the melting point of the mixture is lower than the melting point of either drug or carrier alone. At the eutectic composition (e), both drug and carrier exist in finely divided state, which results in higher surface area and enhanced dissolution rate of drug. This was first reported for sulfathiazole-urea^{10,11}. Other examples of

eutectic mixture include acetaminophen-urea¹² and the dispersion of griseofulvin and tolbutamide in polyethylene glycol (PEG)-2000¹³.

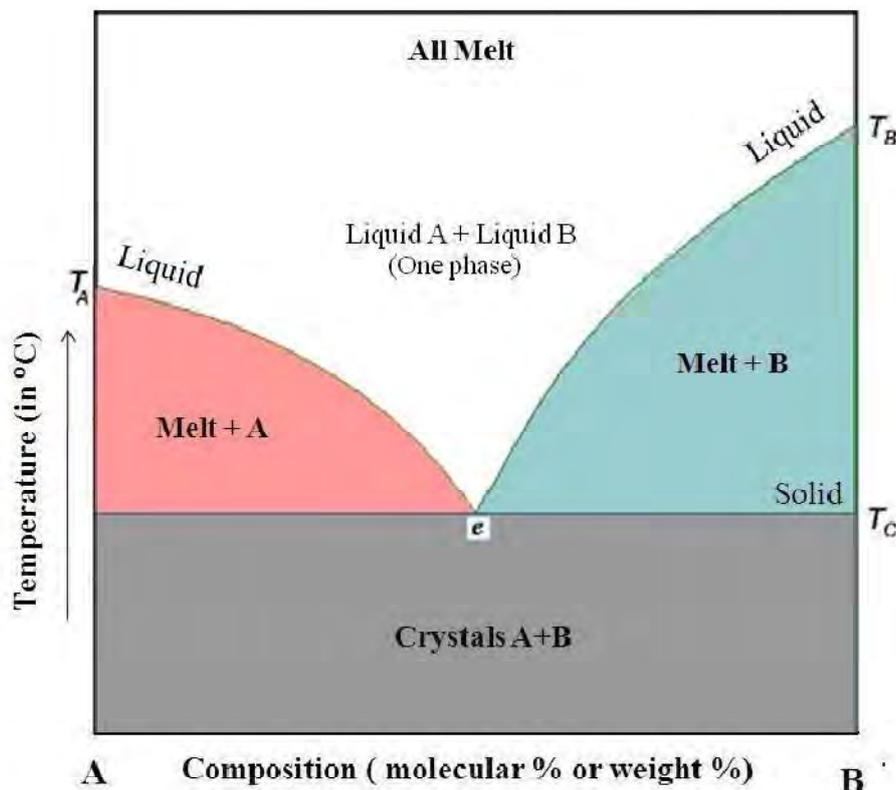


Figure 1: Phase diagram of a eutectic mixture

1.4.2.4. Crystalline Solid Dispersion

A crystalline solid dispersion (or suspension) is formed when the rate at which drug crystallizes from drug-polymer miscible mixture is greater than the rate at which drug-polymer fluid mixture solidifies⁹.

1.4.2.5. Amorphous Solid Dispersion

If the drug-polymer fluid mixture is cooled at a rate that does not allow for drug crystallization, then drug is kinetically trapped in its amorphous or a “solidified-liquid” state. These types of dispersions have the risk of potential for conversion to a more stable and less soluble crystalline form⁹.

1.4.2.6. Solid Solution

Solid solution is a solid dispersion that is miscible in its fluid as well as solid state. These solid solutions may be either of amorphous or crystalline type. In

amorphous solid solutions as the drug is molecularly dispersed in the carrier matrix, its effective surface area is significantly higher and hence the dissolution rate is increased. Amorphous solid solutions have improved physical stability of

amorphous drugs by inhibiting drug crystallization by minimizing molecular mobility¹⁴. Crystalline solid solution may result when a crystalline drug is

trapped within a crystalline polymeric carrier. Poorly soluble drugs have been incorporated in carrier molecules using crystal inclusion and crystal

doping techniques¹⁵, although the usage of such technologies has not yet gained widespread application in pharmaceutical product development. According to extent of miscibility of the two components, solid solutions are continuous or discontinuous type. In continuous solid solutions, the two components are miscible in the solid state in all proportions. The components that are immiscible at intermediate composition, but miscible at extremes of composition are referred to as discontinuous solid solutions. According to the criterion of molecular size of the two components, the solid solutions are classified as substitutional and interstitial¹⁶. In the substitutional solid solution, the solute molecule substitutes for the solvent molecule in the crystal lattice as shown in Figure 2. In this case, the molecular size of the two components should not differ by more than 15%. An interstitial solid solution is obtained when the solute (guest)molecule occupies the interstitial space in the

solvent (host) lattice. For this to occur, the solute molecule diameter should be less than 0.59 than that of solvent molecule¹⁶. Therefore, the volume of the solute molecule(s) should be less than 20% of the solvent molecule(s). Examples include solid solutions of digitoxin, methyltestosterone, prednisolone acetate and hydrocortisone acetate in the matrix of PEG 6000. They all exhibit faster rate of dissolution.

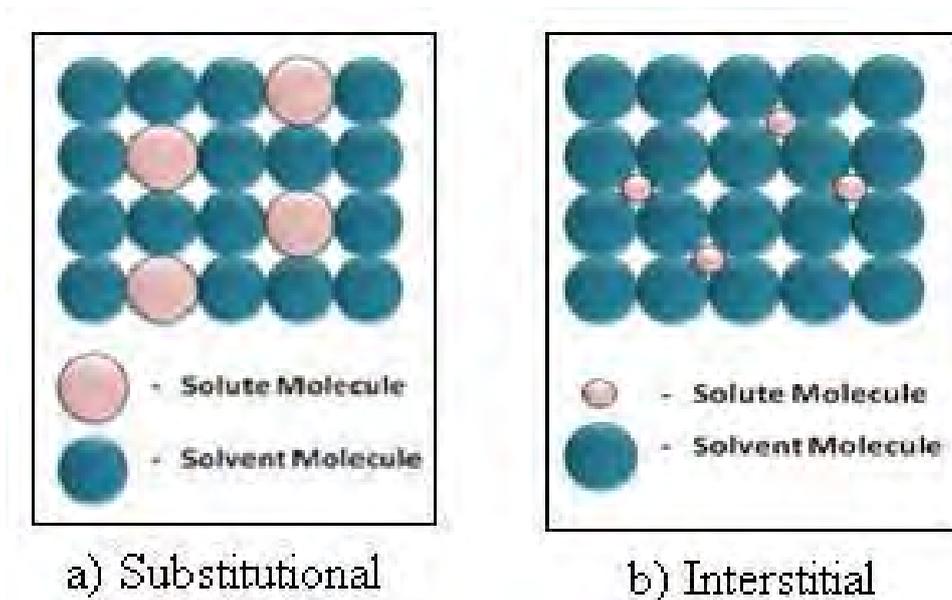


Figure 2: Schematic representation of substitutional and interstitial solid solutions

Goldberg et al., 1965 discussed the theoretical and practical advantages of solid solution over eutectic mixtures. The reason for the improvement in dissolution rate is that drug has no crystal structure in solid solution. Therefore, the energy normally required to break up the crystalline structure of the drug before it can dissolve is not a limitation to the release of the drug from a solid solution. A further way in which a solid solution could enhance dissolution is through improvement of the wettability of the drug. Even carriers that are not surface active, e.g. urea and citric acid, can improve wetting characteristics. If carriers with surface activity such as cholic acid, bile salts, lecithine, are used the improvement in wetting can be much greater.

MATERIALS AND METHOD:

Materials

The drug, excipients, chemicals/reagents used for various experiments are enlisted as follows. All other chemicals and reagents used were of analytical reagent (AR) grade.

Table 1: List of materials used

Sr. No.	Name of materials	Manufacturer/Supplier
1	Atovaquone	Macleods pharmaceuticals, India
2	Satrinidazole	Macleods pharmaceuticals, India
3	Polyvinylpyrrolidone K30 (PVP K30)	Macleods pharmaceuticals, India
4	Poly ethylene glycol 4000	Macleods pharmaceuticals
5	Methanol	Macleods pharmaceuticals
6	Ethanol	Macleods pharmaceuticals
7	Concentration Hydrochloric acid	Macleods pharmaceuticals

Equipments

Table 2: List of apparatus/ equipments/ instruments used

Sr. no.	Equipments/ Instruments	Source
1	UV –Visible Double Beam Spectrophotometer	Macleods pharmaceuticals
2	Fourier Transform Infra-Red Spectrophotometer	Macleods pharmaceuticals
3	Hot-air Oven	Macleods pharmaceuticals
4	Dissolution Test Apparatus USP XXII (Type-II)	Macleods pharmaceuticals
5	Electronic Weighing Balance (single pan)	Macleods pharmaceuticals
6	Digital pH Meter	Macleods pharmaceuticals
7	Differential Scanning Calorimeter	Macleods pharmaceuticals
8	X-Ray Diffractometer	Macleods pharmaceuticals

RESULTS AND DISCUSSION

RESULTS

1. Preformulation study

Physical characters of Atovaquone were found as

Table 3: Physical characters of Atovaquone drug

Sr.no.	Characters	Inference
1	Nature	crystalline powder
2	Colour	Dark Yellow
3	Odor	Odorless
4	Taste	Slightly Bitter
5	Melting point	219-221°C
6	Solubility- In methanol In water In ethanol	Soluble Practically insoluble Freely soluble
7	Bulk density	0.217 gm/cm ³
8	Tapped density	0.385 gm/cm ³

Physical characters of Satrinidazole drug were found as

Table 4: Physical characters of Satrinidazole drug

Sr.no.	Characters	Inference
1	Nature	Crystalline powder
2	Color	Buff yellow
3	Odor	Odorless
4	Taste	Bitter
5	Melting point	201-204°C
6	Solubility- In methanol In water In ethanol	Soluble Poorly water soluble Freely soluble
7	Bulk density	0.313 gm/cm ³
8	Tapped density	0.357 gm/cm ³

Preparation of solid dispersion:

The solid dispersions of Atovaquone and Satrinidazole were prepared by solvent evaporation method.

Characterization of solid dispersion of Atovaquone and Satrinidazole:

The solid dispersions were characterized by

1. Micromeritics studies
2. Percentage yield of solid dispersion
3. Drug content
4. Solubility study
5. *In-vitro* dissolution study
6. DSC
7. SEM
8. XRD

Micromeritics studies

The results of micromeritics properties of solid dispersion formulations were as below

Table 5: Micromeritics studies of pure drugs and solid dispersion formulations

Parameters	Bulk density (g/cm ³)*	Tapped density (g/cm ³)*	Percentage Compressibility index	Hausner's ratio	Angle of repose
Formulation code					
A1	0.217	0.385	43.48	1.77	46°25'
B1	0.323	0.327	9.68	1.1	27°15'
C1	0.333	0.37	10	1.11	30°14'
A2	0.313	0.357	12.5	1.14	31°47'
B2	0.294	0.334	11.76	1.13	30°46'
C2	0.334	0.385	13.33	1.15	28°18'

Percentage yield

The results of percentage yield of binary solid dispersion formulations were as below

Table 6: Percentage yield of solid dispersion formulations

Sr. no.	Formulation code	Percentage yield*
1	B1	79.91
2	C1	75.44
3	B2	75.16
4	C2	71.85

Drug content

The results of drug content of pure drug and their solid dispersion formulations were as below

Table 7: Percent drug content of solid dispersion formulations

Sr. no.	Formulation code	Percent drug content
1	B1	96.83
2	C1	89.46
3	B2	98.45
4	C2	96.55

Solubility study

The results of solubility study of binary solid dispersion formulations were as below

Table 8: Solubility ($\mu\text{g/ml}$) of pure drug and solid dispersion formulations

Sr. no.	Formulation code	Solubility ($\mu\text{g/ml}$)
1	A1	12.657
2	B1	40.880
3	C1	22.789
4	A2	12.75
5	B2	43.815
6	C2	16.151

***In-vitro* dissolution studies of solid dispersion formulations**

Table 9: Percent Drug release of pure drugs and solid dispersion formulations

Time (min)	Percentage of drug release (%)					
	A1	B1	C1	A2	B2	C2
0	0	0	0	0	0	0
5	0.740	9.68	1.35	15.43	19.01	1.43
10	4.08	14.86	23.23	38.53	29.96	25.57
15	8.97	21.31	40.54	46.85	33.82	27.60
20	18.72	29.79	35.41	43.73	38.75	31.02
30	20.01	33.83	49.22	51.06	42.78	32.69
45	24.96	43.16	45.44	61.92	43.94	37.69
60	26.43	54.48	49.49	65.80	51.33	48.96

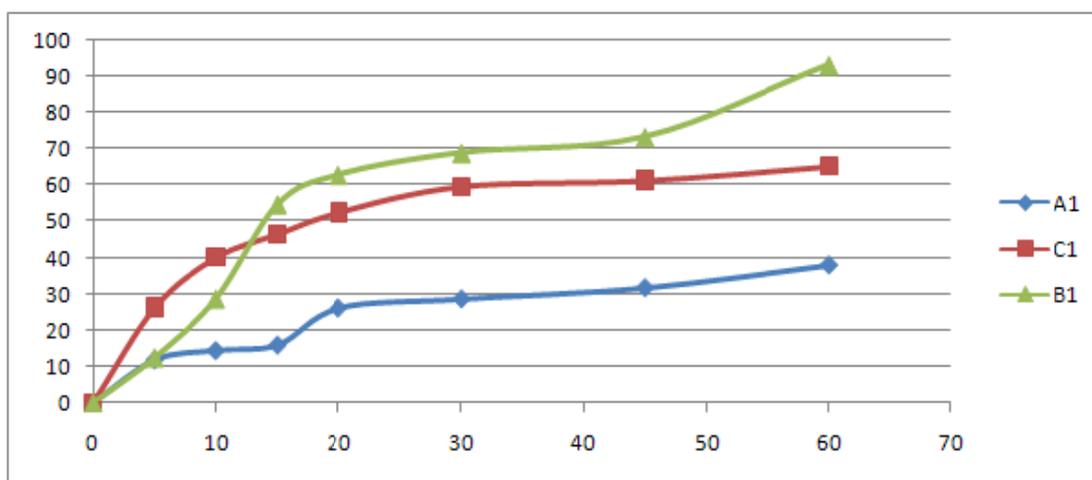


Figure 3: *In-vitro* dissolution profile of Atovaquone pure drug and its solid dispersion formulations

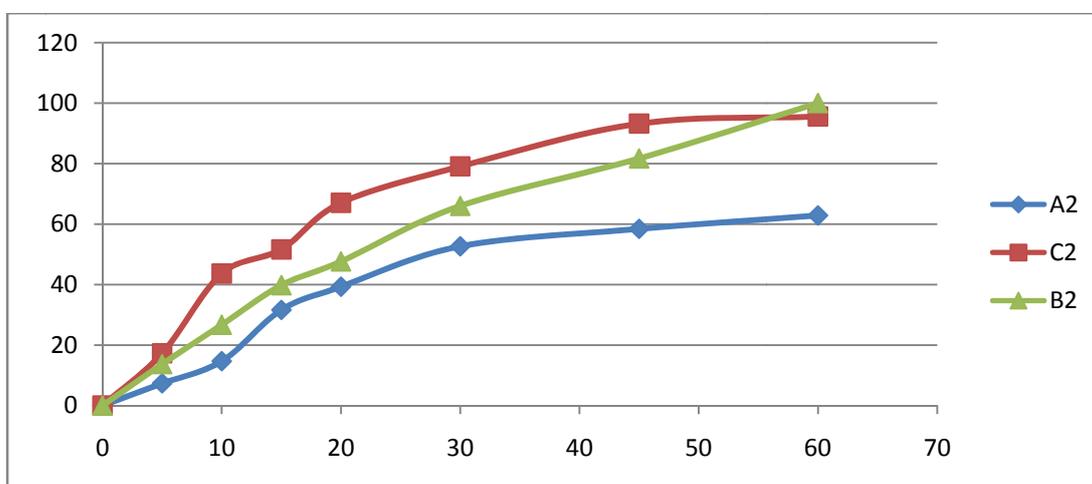


Figure 4: *In-vitro* dissolution profile of Satrinidazole pure drug and its solid dispersion formulations

SUMMARY AND CONCLUSION

Dissolution of drug is rate determining step for oral absorption of poorly water soluble drugs, which subsequently affect the *in-vivo* absorption of drug. Solubility is the key parameter for the oral bioavailability of poorly water soluble drugs. Atovaquone and Satrinidazole are poorly soluble drugs and it also has poor bioavailability. Therefore many strategies have been worked out to improve its aqueous solubility as well as its release rate from various solid dosage forms and also improve the flow property for easily compression more are under constant investigation. In the present study, solid dispersion technique was evaluated for enhancement of solubility and the dissolution rate. Therapeutic effectiveness of a drug depends upon the bioavailability and ultimately upon the solubility of drug molecules. The products obtained by all these means were appropriately characterized and evaluated for enhancement of solubility and for their *in-vitro* dissolution.

Atovaquone and Satrinidazole are potent antiprotozoal agent having high lipophilicity and poor aqueous solubility. It shows slow and variable absorption when administered orally. Thus the objective of the study was to formulate solid dispersion of both the drug, in order to achieve a better dissolution rate which would further help in enhancing its oral bioavailability. Solid dispersion prepared with hydrophilic polymer showed a higher enhancement in solubility rate with PEG4000 i.e. 2-3 fold as compared to 1.2 fold for that prepared with PVPK30. Further analysis was done on formulation prepared with Lipoid S100. DSC data indicated a depression in melting temperature and enthalpy for the formulation. XRD results indicated no change in crystal structure of drug in formulation. Lack of chemical interaction between drug and carrier was confirmed by the FT-IR spectra. The *in vitro* dissolution studies showed a significant increase in the dissolution rate of solid dispersions of Atovaquone and Satrinidazole as compared with pure drug, and physical mixtures of satranidazole with PEG 4000 and PVP K30.

Thus from the various studies conducted it may be concluded that solid dispersions of the poorly water soluble drug satranidazole and Atovaquone were successfully prepared by solvent evaporation method using hydrophilic polymers PEG 4000 and PVP K30. Therefore, it can be concluded that the solubility and the dissolution rate of poorly water soluble drug Atovaquone and satranidazole can be significantly enhanced by preparation of solid dispersions using hydrophilic polymers by solvent evaporation method.

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