

## Research Article

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## Solid Dispersions: an Approach to Enhance Solubility of poorly Water Soluble Drug

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### Abstract

Solid dispersions have attracted considerable interest as an efficient means of improving the dissolution rate and hence the bioavailability of a range of poorly water-soluble drugs. Solid dispersions of poorly water-soluble drugs with water-soluble carriers has reduced the incidence of these problems and enhanced dissolution. The focus of this review article is on the advantages, limitations, various methods of preparation and characterization of the solid dispersion. The different types of solid dispersions based on their molecular arrangement have been highlighted. Some of the practical aspects to be considered for the preparation of solid dispersions, such as selection of carrier and methods of physicochemical characterization have also been discussed. In this review, it is intended to discuss the future prospects related to the area of solid dispersion manufacturing.

**Keywords:** Solid dispersion, Carriers, Solubility, Dissolution rate, Bioavailability.

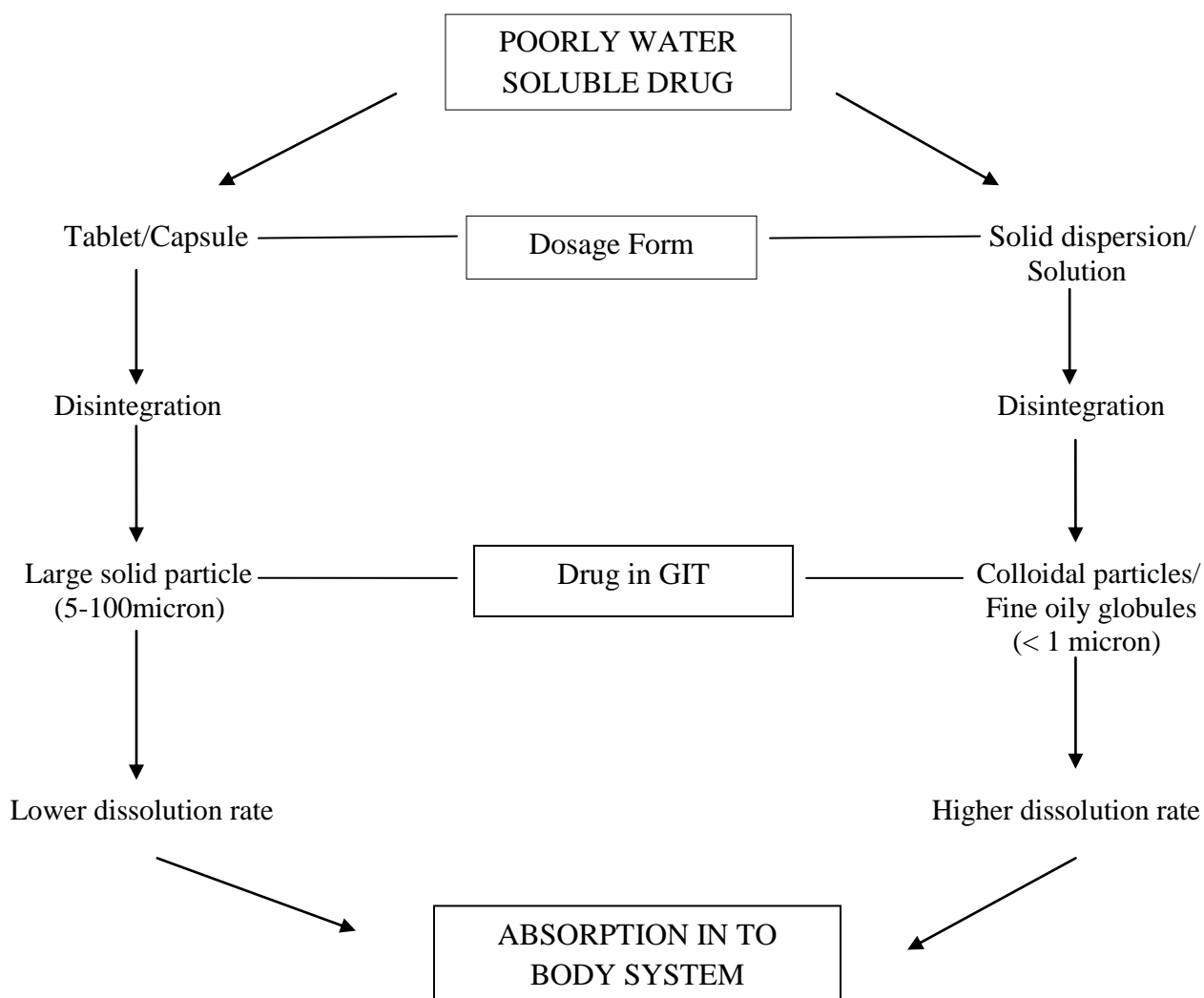
### Introduction

Oral drug delivery is by far the most preferable route of drug administration due to ease of administration, patient compliance, flexibility in formulation, etc. However in case of the oral route there are several challenges such as limited drug absorption resulting in poor bioavailability and poor pharmacological response resulting into inadequate and erratic oral absorption.<sup>1</sup>

Drug absorption from the gastrointestinal (GI) tract can be limited by a variety of factors with the most significant contributors being poor aqueous solubility and/or poor membrane permeability of the drug molecule. When delivering an active agent orally, it must first dissolve in gastric and/or intestinal fluids before it can then permeate the membranes of the GI tract to reach systemic circulation. Therefore, 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 absorption. Hence, two areas of pharmaceutical research that focus on improving the oral bioavailability of active agents include enhancing solubility and dissolution rate of poorly water-soluble drugs and enhancing permeability of poorly permeable drugs. This article focuses on the former, in particular, the use of solid dispersion technologies to improve the dissolution characteristics of poorly water-soluble drugs and in turn their oral bioavailability. Numerous solid dispersion systems have been demonstrated in the pharmaceutical literature to improve the dissolution properties of poorly water-soluble drugs.<sup>2</sup>

Most of the new chemical entities (NCE) under development now-a-days are intended to be used as a solid dosage form that originates an effective and reproducible in vivo plasma concentration after oral administration due to many advantageous features of this route like greater stability, smaller bulk, accurate dosage and easy production. But the fact is most NCEs are poorly water soluble drugs, not well-absorbed after oral administration and the oral delivery of such drugs is frequently associated with low bioavailability, high intra- and inter-subject variability, and a lack of dose proportionality. It has been estimated that 40% of new chemical entities currently being discovered are poorly water-soluble. To overcome the problems associated with oral absorption and bioavailability issue, various strategies have been utilized including prodrug formation, complexation, microcapsulation, the use of surfactants, lipids, permeation enhancers, micronization, salt formation, cyclodextrins,

nanoparticles, solid dispersions and self emulsifying drug delivery system.<sup>3</sup> One such formulation approach that has been shown to significantly enhance absorption of such drugs is to formulate solid dispersion. The term solid dispersion refers to a group of solid products consisting of at least two different components, generally a hydrophilic matrix and a hydrophobic drug. The matrix can be either crystalline or amorphous. When the solid dispersion is exposed to aqueous media, the carrier dissolves and the drug releases as fine colloidal particles. The resulting enhanced surface area produces higher dissolution rate and enhances bioavailability of poorly water soluble drugs. In addition, in solid dispersions, a portion of drug dissolves immediately to saturate the gastrointestinal tract fluid, and excess drug precipitates as fine colloidal particles or oily globules of submicron size.<sup>4</sup> The advantage of solid dispersions over conventional tablet or capsule is shown schematically in Figure 1.



**Figure 1:** A schematic representation of the bioavailability enhancement of a poorly water- soluble drug by solid dispersion compared with conventional tablet or capsule

**Classification of solid dispersions**

The drug can be dispersed molecularly, in amorphous particles (clusters) or in crystalline particles by melting or

solvent method. Therefore, based on their molecular arrangement, different types of solid dispersions (SDs) can be distinguished. They are described in Table 1.<sup>4</sup>

**Table 1: Types of solid dispersions**

Sr. No.	Solid dispersion type	Matrix *	Drug **	Remarks	No.	Phase s	Ref. to lit.
1.	Eutectics	C	C	First type of solid dispersion prepared		2	(Chiou and Riegelman, 1971)
2.	Amorphous precipitations in crystalline matrix	C	A	Rarely encountered		2	(Breitenbach AH, 2002); (Mullins and Macek, 1960)
3.	Solid solutions	-	-	-		-	-
i	Continuous solid solutions	C	M	Miscible at all composition, never prepared		1	(Goldberg <i>et al.</i> , 1965]
ii	Discontinuous solid solutions	C	M	Partially miscible, 2 phases even though drug is molecularly dispersed		2	Sekiguchi K and Obi N (1961)
iii	Substitutional solid solutions	C	M	Molecular diameter of drug (solute) differs less than 15% from the matrix (solvent) diameter. In that case the drug and matrix are substitutional. Can be continuous or discontinuous. When discontinuous: 2 phases even though drug is molecularly dispersed.		1or2	(Rastogi and Verma, 1956); (Wilcox <i>et al.</i> , 1964)
4.	Interstitial solid solutions	C	M	Drug (solute) molecular diameter less than 59% of matrix (solvent) diameter. Usually limited miscibility, discontinuous. Example: Drug in helical interstitial spaces of PEG.		2	(Chiou and Riegelman, 1971); (Chiou and Riegelman, 1969)
5.	Glass suspension	A	C	Particle size of dispersed phase dependent on cooling/evaporation rate. Obtained after crystallization of drug in amorphous matrix		2	(Chiou and Riegelman, 1971); (Sarkari M <i>et al.</i> , 2002)
6.	Glass suspension	A	A	Particle size of dispersed phase dependent on cooling/evaporation rate. Many solid dispersions are of this type		2	(Chiou and Riegelman, 1971); (Sarkari M <i>et al.</i> , 2002)
7.	Glass solution	A	M	Requires miscibility OR solid solubility, complex formation upon fast cooling OR evaporation during preparation, many (recent) examples especially with PVP		1	Simonelli AP <i>et al.</i> , 1969

\* A: matrix in the amorphous state, C: matrix in the crystalline state

\*\* A: drug dispersed as amorphous clusters in the matrix, C: drug dispersed as crystalline particles in the matrix, M: drug molecularly dispersed throughout the matrix

### **Selection of the Carrier**

The selection of the carrier has the influence on the dissolution characteristics of the dispersed drug, since the dissolution rate of one component from the surface is affected by the other component in a multiple component mixture. Therefore, a water-soluble carrier results in a faster release of the drug from the matrix. A poorly soluble or insoluble carrier leads to slower release of a drug from the matrix. If the active drug present is a minor component in the dispersion, faster release of a drug can be achieved from matrix.<sup>2</sup>

### **Advantages of solid dispersions**

Management of the drug release profile using solid dispersions is achieved by manipulation of the carrier and solid dispersion particles properties. Parameters, such as carrier molecular weight and composition, drug crystallinity and particle porosity and wettability, when successfully controlled, can produce improvements in bioavailability.<sup>4</sup>

1. Particles with reduced particle size: 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.<sup>3</sup>

2. Particles with improved wettability: Wettability is improved during solid dispersion production. It has been suggested that the presentation of particles to the dissolution medium as physically separate entities may reduce aggregation. In addition, many of the carriers used for solid dispersions may have some wetting properties; hence improved wetting may lead to reduced agglomeration and increased surface area.<sup>3,5</sup>

3. Particles with higher porosity: Particles in solid dispersions have been found to have a higher degree of porosity. The increase in porosity also depends on the carrier properties; for instance, solid dispersions containing linear polymers produce larger and more porous particles than those containing reticular polymers and, therefore, result in a higher dissolution rate. The increased porosity of solid dispersion particles also hastens the drug release profile.<sup>2</sup>

4. Drugs in amorphous state: Poorly water soluble crystalline drugs, when in the amorphous state tend to have higher solubility. Drug in its amorphous state shows higher drug release because no energy is required to break up the crystal lattice during the dissolution process. In solid dispersions, drugs are presented as supersaturated solutions after system dissolution, and it is speculated that, if drugs precipitate, it is as a metastable polymorphic form with higher solubility than the most stable crystal form.<sup>5,6</sup>

### **Disadvantages of solid dispersions**

1. They are not broadly used in commercial products because there is the possibility that during processing (mechanical stress) or storage (temperature and humidity stress) the amorphous state may undergo crystallization.

2. The effect of moisture on the storage stability of amorphous pharmaceuticals is also a significant concern, because it may increase drug mobility and promote drug crystallization.

3. Most of the polymers used in solid dispersions can absorb moisture, which may result in phase separation, crystal growth or conversion from the amorphous to the crystalline state or from a metastable crystalline form to a more stable structure during storage. This may result in decreased solubility and dissolution rate. Therefore, exploitation of the full potential of amorphous solids requires their stabilization in solid state, as well as during in vivo performance.

4. Poor scale-up for the purposes of manufacturing.

5. Laborious and expensive methods of preparation.

6. Reproducibility of physicochemical characteristics.

7. Difficulty in incorporating into formulation of dosage forms.

8. Scale-up of manufacturing process.

9. Stability of the drug and vehicle.<sup>3-6</sup>

### **Pharmaceutical Applications of Solid dispersion**

The pharmaceutical applications of solid dispersion techniques include:

1. To increase the solubility of poorly soluble drugs thereby enhance the dissolution rate, absorption and bioavailability. .
2. To obtain a homogeneous distribution of a small amount of drug in solid state.
3. To stabilize unstable drugs and protect against decomposition by processes such as hydrolysis, oxidation, racemization, photo oxidation etc.
4. To dispense liquid or gaseous compounds;
5. To formulate a fast release priming dose in a sustained release dosage form;
6. To formulate sustained release preparation of soluble drugs by dispersing the drug in poorly soluble or insoluble carrier;
7. To reduce side effects-(a) the binding ability of drugs for example to the erythrocyte membrane is decreased by

making its inclusion complex, (b) the damage to the stomach mucous membranes by certain non-steroidal anti-inflammatory drugs can be reduced by administration as an inclusion compound;

8. To mask unpleasant taste and smell and avoid undesirable incompatibilities.

9. To convert liquid compounds into formulations. Liquid drugs can be manufactured as solid drug formulations such as powders, capsules or tablets e.g., unsaturated fatty acids, essential oils, nitroglycerin, benzaldehyde, prostaglandin, clofibrate etc.

10. To reduce pre systemic inactivation of drugs like morphine and progesterone.<sup>2,5</sup>

### Preparation of Solid Dispersions

Various methods are used for preparation of solid dispersion system. These methods are depicted in figure 2.<sup>4</sup>

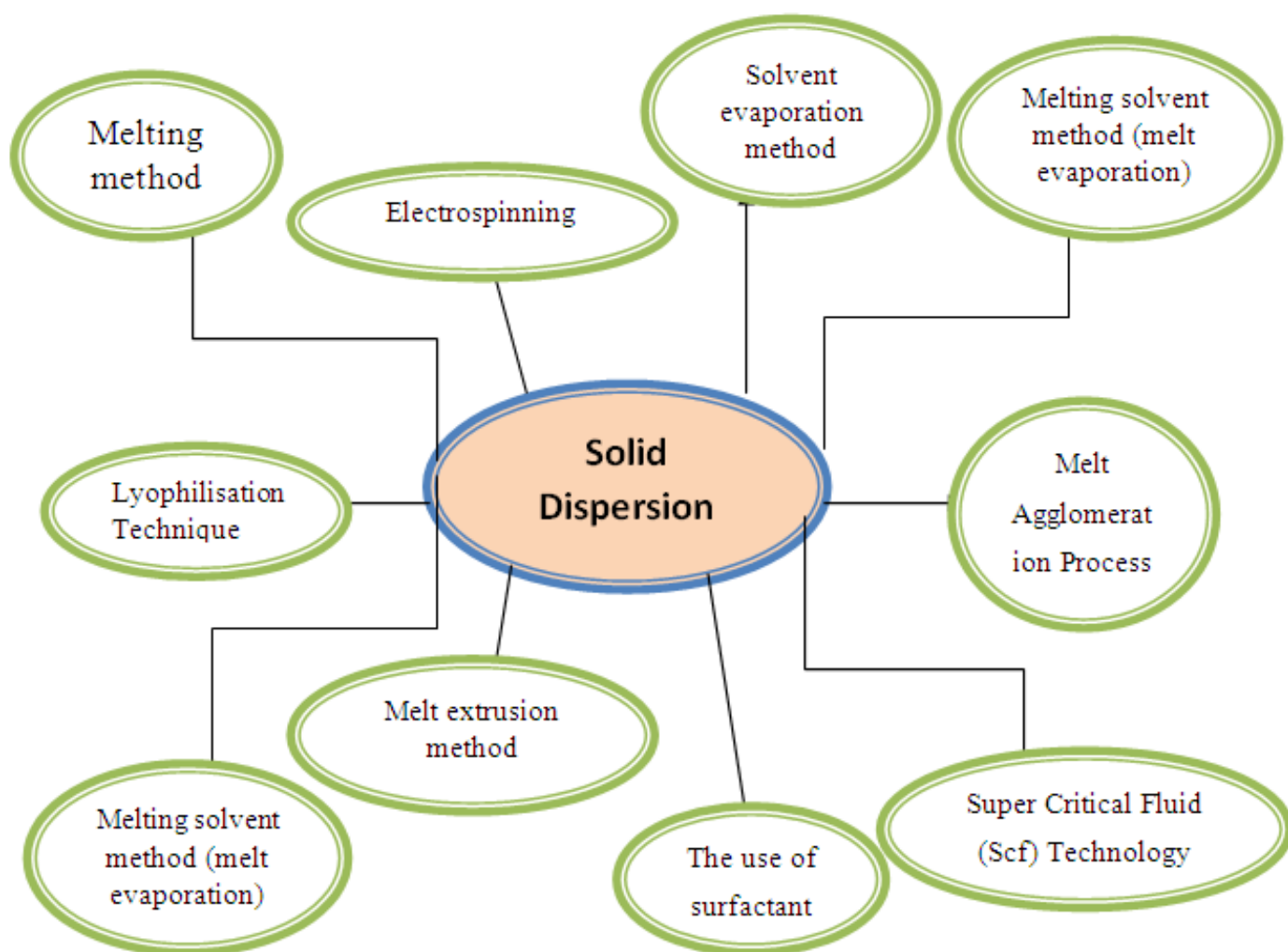


Figure 2: Methods of preparation of solid dispersions

1. Fusion / Melting method
2. Solvent method
3. Melting solvent method (melt evaporation)
4. Melt extrusion methods
5. Lyophilization techniques
6. Melt agglomeration Process
7. The use of surfactant
8. Electrospinning
9. Super Critical Fluid (Scf) technology

### **1. Fusion method**

The melting or fusion method is the preparation of physical mixture of a drug and a water-soluble carrier and heating it directly until it melts. The melted mixture is then solidified rapidly in an ice-bath under vigorous stirring. The final solid mass is crushed, pulverized and sieved. Appropriately this has undergone many modifications in pouring the homogenous melt in the form of a thin layer onto a ferrite plate or a stainless steel plate and cooled by flowing air or water on the opposite side of the plate. In addition, a super-saturation of a solute or drug in a system can often be obtained by quenching the melt rapidly from a high temperature. Under such conditions, the solute molecule is arrested in the solvent matrix by the instantaneous solidification process. The quenching technique gives a much finer dispersion of crystallites when used for simple eutectic mixtures. However many substances, either drugs or carriers, may decompose during the fusion process which employs high temperature. It may also cause evaporation of volatile drug or volatile carrier during the fusion process at high temperature. Some of the means to overcome these problems could be heating the physical mixture in a sealed container or melting it under vacuum or in presence of inert gas like nitrogen to prevent oxidative degradation of drug or carrier.

The main advantages of this method are its simplicity and economy. The disadvantages are: i) that the method is only applied when the drug and matrix are compatible and when they mix well at the heating temperature. When the drug and matrix are incompatible two liquid phases or suspension can be observed in the heated mixture which results in an inhomogeneous solid dispersion and this problem can be prevented by using surfactants. ii) Another problem may arise during cooling when the drug-matrix

miscibility changes. In this case phase separation can occur. Indeed, it was observed that when the mixture was slowly cooled, crystalline drug occurred, whereas fast cooling yielded amorphous solid dispersions. iii) Many substances, either drugs or carriers, may decompose during the fusion process at high temperatures.<sup>4-6</sup>

### **2. Solvent method**

The first step in the solvent method is the preparation of a solution containing both matrix material and drug. The second step involves the removal of solvent(s) resulting in formation of a solid dispersion. Mixing at the molecular level is preferred, because this leads to optimal dissolution properties. The main advantage of the solvent method is thermal decomposition of drugs or carriers can be prevented because of the relatively low temperatures required for the evaporation of organic solvents. However, using the solvent method the pharmaceutical engineer faces two challenges. The first challenge is to mix both drug and matrix in one solution, which is difficult when they differ significantly in polarity. To minimize the drug particle size in the solid dispersion, the drug and matrix have to be dispersed in the solvent as fine as possible, preferably drug and matrix material are in the dissolved state in one solution. Low drug concentrations are used to dissolve both drug and matrix material in water, but this requires evaporation of tremendous amounts of solvent, making the process expensive and impractical. Solubilizers like cyclodextrins or surfactants like Tween80® increase the aqueous solubility of the drug substantially. However, the amounts of solubilizers or surfactants in the final product are often eminent. Moreover, only dosage forms with low drug loads are possible. In addition, they are not always tolerated well in the body or may even be toxic. The second challenge in the solvent method is to prevent phase separation, e.g. crystallization of either drug or matrix, during removal of the solvent(s). Drying at high temperatures speeds up the process and reduces the time available for phase separation. On the other hand, at high temperatures the molecular mobility of drug and matrix remains high, favoring phase separation (e.g., crystallization). To dry the solutions, vacuum drying moderate heating is often used. Sometimes, the solvent evaporation is accelerated by using a rotary evaporator. Afterwards the formed solid dispersion is often stored in vacuum desiccators to remove the residual solvent. Another drying technique is spray drying. For these reasons, hot melt extrusion is the current method of choice for the preparation of solid dispersions.<sup>2, 4, 5</sup>

### **3. Melting solvent method (melt evaporation)**

It involves preparation of solid dispersions by dissolving the drug in a suitable liquid solvent and then incorporating the solution directly into the melt of polyethylene glycol, which is then evaporated until a clear, solvent free film is left. The film is further dried to constant weight. The 5 – 10% (w/w) of liquid compounds can be incorporated into polyethylene glycol 6000 without significant loss of its solid property. Also the liquid solvent used may affect the polymorphic form of the drug, which precipitates as the solid dispersion. This technique possesses unique advantages of both the fusion and solvent evaporation methods. From a practical standpoint, it is only limited to drugs with a low therapeutic dose e.g. below 50 mg and particularly useful for drugs that are thermolabile or have high melting points.<sup>4,7</sup>

### **4. Melt extrusion method**

Hot-stage extrusion (HME) consists of the extrusion, at high rotational speed, of the drug and carrier, previously mixed, at melting temperature for a small period of time. Solid dispersion by this method is composed of active ingredient and carrier, and prepared by hot-stage extrusion using a co-rotating twin-screw extruder. The drug/carrier mix is simultaneously melted, homogenized and then extruded and shaped as tablets, granules, pellets, sheets, sticks or powder. The intermediates can then be further processed into conventional tablets. An important advantage of the hot melt extrusion method is that the drug/carrier mix is only subjected to an elevated temperature for about 1min, which enables drugs that are somewhat thermolabile to be processed. The concentration of drug in the dispersions is always 40% (w/w). Samples are milled for 1 min with a cutting mill and sieved to exclude particles >355 $\mu$ .

A reduction in processing temperature can be achieved by the association of hot-stage extrusion with the use of carbon dioxide as a plasticizer which broadens the application of hot-stage extrusion to thermally labile compounds. HME also offers several advantages over traditional pharmaceutical processing techniques including the absence of solvents, few processing steps, continuous operation, and low temperature, short residence time which prevents the drug-carrier mixture from thermal degradation, more possibility of the formation of solid dispersions and improved bioavailability. This method has several disadvantages these are: (i) high shear forces may produce high local temperature in the extruder therefore it

may create a problem for heat sensitive materials, (ii) just like traditional fusion method, miscibility of drug and carrier matrix can be a problem. Some examples of pharmaceutically approved polymeric materials which are used in hot-melt extrusion include vinyl polymers [polyvinylpyrrolidone (PVP), PVP-vinyl acetate (PVP-VA)], polyethylene oxide (PEO), Eudragit® (acrylates), Polyethylene glycol (PEG) and cellulose derivatives.<sup>5,6</sup>

### **5. Lyophilization Technique (Freeze-drying)**

Lyophilization has been thought of a molecular mixing technique where the drug and carrier are co dissolved in a common solvent, frozen and sublimed to obtain a lyophilized molecular dispersion. This technique was proposed as an alternative technique to solvent evaporation.

The advantages of freeze drying is that the drug is subjected to minimal thermal stress during the formation of the solid dispersion and the risk of phase separation is minimized as soon as the solution is vitrified. An even more promising drying technique is spray-freeze drying. The solvent is sprayed into liquid nitrogen or cold dry air and the frozen droplets are subsequently lyophilized. The large surface area and direct contact with the cooling agent results in even faster vitrification, thereby decreasing the risk for phase separation to a minimum. Moreover, spray freeze drying offers the potential to customize the size of the particle to make them suitable for further processing or applications like pulmonary or nasal administration.<sup>5,6</sup>

### **6. Melt Agglomeration Process**

This technique has been used to prepare solid dispersion wherein the binder acts as a carrier. In addition, solid dispersions are prepared either by heating binder, drug and excipient to a temperature above the melting point of the binder (melt- in procedure) or by spraying a dispersion of drug in molten binder on the heated excipient (spray-on procedure) by using a high shear mixer. The rotary processor might be preferable to the high melt agglomeration because it is easier to control the temperature and because a higher binder content can be incorporated in the agglomerates. The effect of binder type, method of manufacturing and particle size are critical parameters in preparation of solid dispersion by melt agglomeration. It has been found that the melt in procedure gives a higher dissolution rates than the spray-on procedure with PEG 3000, poloxamer 188 and gelucire 50/13 attributed to immersion mechanism of agglomerate formation and growth. In addition the melt in procedure

also results in homogenous distribution of drug in agglomerate. Larger particles results in densification of agglomerates while fine particle cause complete adhesion to the mass to bowl shortly after melting attributed to distribution and coalescence of the fine particles.<sup>4</sup>

### **7. The use of surfactant**

The utility of the surfactant systems in solubilization is very important. Adsorption of surfactant on solid surface can modify their hydrophobicity, surface charge, and other key properties that govern interfacial processes such as flocculation/dispersion, floating, wetting, solubilization, detergency, and enhanced oil recovery and corrosion inhibition. Surfactants have also been reported to cause solvation/plasticization, manifesting in reduction of melting the active pharmaceutical ingredients, glass transition temperature and the combined glass transition temperature of solid dispersions. Because of these unique properties, surfactants have attracted the attention of investigators for preparation of solid dispersions.<sup>4</sup>

### **8. Electrospinning**

Electrospinning is a process in which solid fibers are produced from a polymeric fluid stream solution or melt delivered through a millimeter-scale nozzle. This process involves the application of a strong electrostatic field over a conductive capillary attaching to a reservoir containing a polymer solution or melt and a conductive collection screen. Upon increasing the electrostatic field strength up to but not exceeding a critical value, charge species accumulate on the surface of a pendant drop; destabilize the hemispherical shape into a conical shape (commonly known as Taylor's cone). Beyond the critical value, a charged polymer jet is ejected from the apex of the cone (as a way of relieving the charge built-up on the surface of the pendant drop). The ejected charged jet is then carried to the collection screen via the electrostatic force. The thinning down of the charged jet is limited. If the viscosity increases, the charged jet is dried. This technique has tremendous potential for the preparation of nanofibres and controlling the release of biomedicine, as it is simplest, the cheapest this technique can be utilized for the preparation of solid dispersions in future.<sup>4,6</sup>

### **9. Super Critical Fluid (Scf) Technology**

The supercritical fluid antisolvent techniques, carbon dioxide are used as an antisolvent for the solute but as a solvent with respect to the organic solvent. Different acronyms were used by various authors to denote micronization processes: aerosol solvent extraction system, precipitation with a compressed fluid antisolvent, gas antisolvent, solution enhanced dispersion by supercritical fluids and supercritical antisolvent. Once the drug particles are solubilised within SCF, they may be recrystallised at greatly reduced particle sizes. The flexibility and precision offered by SCF processes allows micronization of drug particles within narrow ranges of particle size, often to sub-micron levels. Current SCF processes have demonstrated the ability to create nanoparticulate suspensions of particles 5-2,000nm in diameter. The SAS process involves the spraying of the solution composed of the solute and of the organic solvent into a continuous supercritical phase flowing concurrently. Use of supercritical carbon dioxide is advantageous as it is much easier to remove from the polymeric materials when the process is complete, even though a small amount of carbon dioxide remains trapped inside the polymer; it poses no danger to the patient. In addition the ability of carbon dioxide to plasticize and swell polymers can also be exploited and the process can be carried out near room temperature. Moreover, supercritical fluids are used to lower the temperature of melt dispersion process by reducing the melting temperature of dispersed active agent. The low operating conditions (temperature and pressure) make SCFs attractive for pharmaceutical research.<sup>4,5</sup>

### **Characterization of solid dispersions**

Several different molecular structures of the drug in the matrix can be encountered in solid dispersions. Several techniques have been available to investigate the molecular arrangement in solid dispersions. However, most effort has been put in to differentiate between amorphous and crystalline material. Various methods include Thermal analysis, DSC, Powder X-ray diffraction method, Spectroscopic methods (FTIR, NMR, Raman spectroscopy) microscopic method (Hot-stage microscopy) and in-vitro dissolution studies.<sup>2,4,5,7</sup>

### **Marketed products**

A list of several marketed products prepared using different solid dispersion techniques is given in table 2.<sup>6</sup>



**Table 2:** Several marketed and late stage drugs designed for improved solubility by solid dispersion techniques

Product/Substance	Dispersion Polymer or Carrier	Technology used	Company
Gris-PEG® (Griseofulvin)	Polyethylene glycol	Melt process; exact process unknown	Novartis
Sporamax capsules (Itraconazole)	Hydroxypropylmethylcellulose (HPMC)	Spray layering	Janseen pharmaceutica
Cesamet®( Nabilone)	Povidone	process unknown	Lilly
Kaletra (lopinavir and ritonavir)	Polyvinylpyrrolidone (PVP)/polyvinyl acetate	Melt-extrusion	Abbott Laboratories
Torcetrapib <sup>a</sup>	HPMC acetate succinate	Spray drying	Pfizer
Ibuprofen	Various	Melt-extrusion	Soliqs
Isoptin SRE-240 (Verapamil)	Various	Melt-extrusion	Soliqs
Rezulin <sup>b</sup> (Troglitazone)	PVP	Melt-extrusion	Pfizer
LCP-Tacro (Tracrolimus)	HPMC	Melt-granulation	Life Cycle Pharma
Intelence (Etravirine)	HPMC	Spray drying	Tibotec
Certican (Everolimus)	HPMC	Melt or Spray drying	Novartis
Afeditab (Nifedipine)	Poloxamer or PVP	Melt/absorb on carrier	Élan Corp

<sup>a</sup> Halted in phase III; <sup>b</sup> Withdrawn from market

### Future prospects of solid dispersions

Despite many advantages of solid dispersions, issues related to preparation, reproducibility, formulation, scale-up and stability limited its use in commercial dosage forms for poorly water soluble drugs. However, successful development has been feasible in recent years due to availability of surface-active and self-emulsifying carriers with relatively low melting points. The drug along with carrier are filled into hard gelatin capsules because of easy manufacturing process and improved bioavailability and enhanced dissolution rate. One of the major focuses for research would be the identification of new surface-active and self-emulsifying carriers for solid dispersion. The other focus would be on identification of vehicles or excipients that would retard or prevent crystallization of drugs from super-saturated systems along with development of extended release dosage forms and

physical and chemical stability of both drug and carrier in solid dispersion.<sup>7</sup>

### Conclusion:

The solid dispersion method is one of the effective approaches to achieve the goal of solubility enhancement of poorly water-soluble drugs. In developing a new solid dispersion system for a given drug, it is important to understand the physicochemical properties of the drug and carrier that best match the properties and find a solid dispersion method. The preparation method and the amount of the carrier also play a vital role in the enhancement of drug dissolution rate.

With future development of this technology, solid dispersions will continue to enable novel applications in drug delivery and solve problems associated with the delivery of poorly soluble drugs.

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