

Research Article

Formulation and *in vitro* Evaluation of Eudragit[®] Microspheres of Stavudine

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Abstract

Purpose: The aim of this study was to formulate and evaluate microencapsulated controlled release preparations of a highly water-soluble drug, stavudine, using Copolymers synthesized from acrylic and methacrylic acid esters (Eudragit RS 100 and RL 100) as the retardant material. .

Methods: Microspheres were prepared by solvent evaporation method using an acetone / liquid paraffin system. Magnesium stearate was used as the droplet stabilizer and n-hexane was added to harden the microspheres. The prepared microspheres were characterized for their micromeritic properties and drug loading, as well by fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry, x-ray powder diffractometry and scanning electron microscopy. The *in vitro* release studies were performed in pH 6.8, phosphate buffer.

Results: The prepared microspheres were white, free flowing and spherical in shape. The drug-loaded microspheres showed 67-91% of entrapment and release was extended upto 6 to 8 h. The infrared spectra and differential scanning calorimetry thermographs showed stable character of stavudine in the drug-loaded microspheres and revealed the absence of drug-polymer interactions. X-ray diffraction patterns showed that there was decrease in crystallinity of the drug. Scanning electron microscopy study revealed that the microspheres were spherical and porous in nature.

Conclusion: The best-fit release kinetics was achieved with Higuchi plot followed by zero order and First order. The release of stavudine was influenced by the drug to polymer ratio and particle size & was found to be diffusion controlled.

KEYWORDS: stavudine, Eudragit, microspheres, controlled release, polymethacrylate.

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INTRODUCTION

The population of patient with chronic disease or complications of other disease has recently been increasing. These situations necessitate taking drug for a long period and / or multiple medicines simultaneously, which can lead to increase in non-compliance. The problem would be worse for drugs with short biological half-life. One method to solve such problems is to find a dosage form capable of releasing the drug gradually. Microencapsulation has been used as one of the methods to deliver drugs in a controlled manner¹. Stavudine (D4T, thymidine) is the FDA-approved drug for clinical use for the treatment of HIV infection, AIDS and AIDS-related conditions either alone or in combination with other antiviral agents. Stavudine is typically administered orally as a capsule and an oral solution. The virustatic drug has a very short half-life (1.30 h). However patients receiving stavudine develop neuropathy and lactic acidosis. The side effects of stavudine are dose-dependent and a reduction of the total administered dose reduces the severity of the toxicity². Microencapsulated techniques have mostly been used for lipophilic drugs since

stearate was used as a droplet stabilizer to prevent droplet coalescence in the oil medium and n-hexane was added as a non-solvent to the processing medium to solidify the microspheres⁵. The effect of various processing and formulation factors such as drug to polymer ratio, stirring speed and surfactant concentration on the mean particle size of microspheres was investigated. The prepared spherical microspheres were evaluated for micromeritic properties and drug content, and also by FTIR, DSC, X-RD, SEM as well as for *in vitro* drug release studies⁶.

MATERIALS AND METHODS

Materials

Stavudine was obtained as a gift from Hetero Labs Ltd. (Hyderabad, India). Eudragit RS 100 and RL 100 was obtained from Röhm Pharma, GmbH, Darmstadt, Germany. All other reagents and solvents used were of pharmaceutical or analytical grade.

Methods

Stavudine microspheres were prepared by solvent evaporation techniques. Different amounts of Eudragit RS or Eudragit RS: RL combination was dissolved in 25 ml acetone

$$\text{Percent yield} = \frac{\text{the amount of microspheres obtained (g)}}{\text{the theoretical amount (g)}} \times 100$$

hydrophilic drugs showed low loading efficiency. The objective of the present investigation was to prepare the controlled release, microspheres of stavudine by improving biological half-life and entrapment efficiency. One method of ensuring high entrapment efficiency of water-soluble active ingredients is to use a hydrophobic processing medium into which the hydrophilic drug molecule is unlikely to migrate out³.

In this present study, stavudine microspheres were prepared by solvent evaporation technique using Eudragit RS 100 and RL 100 as a matrix polymer⁴. Liquid paraffin and acetone system were used for the preparation of microspheres. Magnesium

separately by using a magnetic stirrer (Remi Equipments, model 2MIH). Pure stavudine (1 g previously dissolved in 10 ml methanol) and magnesium stearate [100 mg] were dispersed in the polymer solution. The resulting dispersion was then poured into 1000 ml beaker, containing the mixture of 270 ml liquid paraffin light and 30 ml n-hexane, while stirring. A mechanical stirrer with a blade [4 cm diameter] (Remi Motors, Model No.RO-123R, Mumbai) was used. Stirring (at 500-700 rpm) was continued for 3 h, until acetone evaporated completely. After evaporation of acetone, the microsphere formed were filtered using Whatman no.1 filter paper. The residue was washed with 4-5 times in 50 ml

petroleum ether (40^o C-60^o C) each. Microspheres were dried at room temperature for 24 h. Formulations containing 1, 2 and 3 g of Eudragit RS only were assigned batch code as: FA₁, FA₂ and FA₃ respectively and formulation with Eudragit RS: RL combinations as, 0.8:0.2, 1.8:0.2 and 2.8:0.2 g were assigned batch code: FA₄, FA₅ and FA₆ respectively. All batches were prepared in triplicate.

Microspheres dried at room temperature were then weighed and the yield of microspheres preparation was calculated using the following formula⁶:

Measurement of Micromeritic properties of microspheres

Measurement of Micromeritic properties of microspheres

Σ (Mean particle size of the fraction X weight fraction)

$$\text{Mean particle size} = \frac{\Sigma (\text{Mean particle size of the fraction X weight fraction})}{\Sigma \text{ Weight fraction}}$$

The flow properties of prepared microspheres were investigated by measuring the bulk density, tapped density, Carr's index and packing factor. The bulk and tapped densities were measured in a 10 ml graduated measuring cylinder. The sample contained in the measuring cylinder was tapped mechanically by means of constant velocity rotating cam. The initial bulk volume and final tapped volume were noted from which, their respective densities were calculated. Each experiment was carried out in triplicate.

Drug entrapment efficiency

About 50 mg of accurately weighed drug-loaded microspheres were added to 50 ml of phosphate buffer, pH 6.8. The resulting mixture was shaken in a mechanical shaker for 24 h. The solution was filtered with a 0.45 μm pore size filter and 1 ml of this solution was appropriately diluted to 25 ml using phosphate buffer, pH 6.8, and analyzed spectrophotometrically at 266 nm using Systronic

2101 UV-Visible double beam Spectrophotometer.

Scanning Electron microscopy (SEM)

Scanning electron microscope (JEOL JSM -5200) was used to characterize the Shape and surface topography of the microspheres⁸. Prior to examination, samples were gold sputter-coated to render them electrically conductive.

Fourier Transform Infrared Spectroscopy (FTIR)

Drug-polymer interactions were studied by FTIR spectroscopy. The spectra were recorded for pure drug and drug-loaded microspheres using FTIR JASIO (Model No. 410). Samples were prepared in KBr disks (2 mg sample in 200 mg KBr). The scanning range was 400-4000 cm^{-1} and the resolution was 2 cm^{-1} .

Differential Scanning Calorimetry (DSC)

The DSC analysis of pure drug and drug-loaded microspheres were carried out using a Diamond DSC (Perkin Elmer, USA) to evaluate any possible drug-polymer interaction⁹. The analysis was performed at a rate 5.00^o C min^{-1} from 50^o C to 200^o C temperature range under nitrogen flow of 25 ml min^{-1} .

X-ray powder Diffraction [X-RD]

X-ray powder diffraction was carried out to investigate the effect of microencapsulation process on crystallinity of drug. Powder X-RD patterns were recorded on Rigaku, Japan (Model-MenifleX) using Ni-filtered, $\text{CuK}\alpha$ radiation, a voltage of 30 kV and a current of 25 mA. The scanning rate employed was 2^o min^{-1} , over the 4^o to 40^o diffraction angle (2 θ) range. The X-RD patterns of drug powder and drug-loaded microspheres were recorded.

Drug release studies

The *in vitro* release studies of drug-loaded microspheres were carried out at 37^o C

and 100 rpm using phosphate buffer pH 6.8 (500 ml) in a USP dissolution apparatus (LABINDIA, DISSO-2000, Mumbai, India) under sink conditions. Accurately weighed samples of microspheres (containing approx. 50 mg of drug, size fraction 250 μm) were added to dissolution medium and at preset time intervals 2 ml aliquots were withdrawn and replaced by an equal volume of fresh dissolution medium. After suitable dilution, the samples were analyzed spectrophotometrically at 266 nm. The concentration of stavudine in test samples was corrected and calculated using a regression equation of the calibration curve.

Release Kinetics

Data obtained from *in vitro* release studies were fitted to various kinetics equations¹⁰ to find out the mechanism of drug release from microspheres. The kinetics models used were zero order, first order, and Higuchi models. The rate constants were also calculated for the respective models.

RESULTS & DISCUSSION

Effect of various processing and formulation parameters on mean particle size

It was observed that when the speed of stirrer was below 500 rpm, there was no formation of spherical microspheres. This could be due to inadequate agitation to disperse the inner phase in the total mass. Therefore, particles were found to settle at the bottom of vessel. At stirrer speeds of 700-1000 rpm, the resulting high turbulence, caused frothing and adhesion to the container wall. Therefore, the mean particle size of microspheres decreased. The desired spherical microspheres were obtained at stirring speeds of 500-700 rpm. When 50 mg magnesium stearate was incorporated, microspheres were not formed because the low magnesium content failed to prevent droplet coalescence in the oil medium; as a result mean particle size was increased. The mean particle size decreased with

increasing amount of magnesium stearate (150 mg). This is probably a consequence of stabilization of the oil droplets with magnesium stearate. Spherical microspheres were formed when the magnesium stearate content was maintained at 100 mg. When the drug: polymer ratio was 1: 1, there was formation of microspheres with small and irregular size, and as the polymer concentration was increased, solution viscosity also increased, resulting in large particles. Thus, mean particle size also increased.

Flow properties of Microspheres

The flow properties are expressed in terms of Carr's Index (see **Table 1.**). The Carr's index for all formulations was less than 20, which indicates excellent flow compared to the original drug crystals. Also the microspheres were found to exhibit higher packing properties than the original drug crystals. The improvement in flow properties suggests that the microspheres can be easily handled during processing.

Scanning Electron Microscopy (SEM)

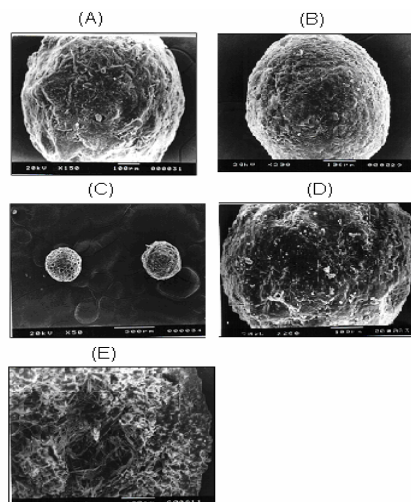


Fig. 1. SEM photographs of Eudragit RS microspheres, before and after dissolution (A and C), Eudragit RS: RL microspheres before and after dissolution (B and D), cross-section of RS: RL microsphere (E).

SEM study shows that particles were spherical. Stavudine shows an endotherm at 166^o C., which

Table 1. Physical characteristics of the microspheres.

Batch Code	Yield (%)	Mean Particle Size (µm)	Entrapment efficiency	Carr's Index	Packing Factor
Stavudine	***	***	***	27.62 ± 0.615	1.37 ± .015
FA ₁	83 ± 6.30	466 ± 17.34	91.71 ± 1.46	8.87 ± 2.30	1.06 ± 0.023
FA ₂	87 ± 3.90	534 ± 21.99	87.35 ± 1.59	10.45 ± 4.39	1.12 ± 0.083
FA ₃	93.43 ± 1.87	600 ± 30.61	80.67 ± 1.34	13.59 ± 4.57	1.19 ± 0.047
FA ₄	82.12 ± 5.77	463 ± 12.66	86.33 ± 0.77	6.74 ± 1.91	1.06 ± 0.023
FA ₅	90.93 ± 1.68	545 ± 15	79.42 ± 1.10	8.49 ± 2.78	1.07 ± 0.037
FA ₆	91.42 ± 3.78	609 ± 22.69	67.92 ± 1.60	9.55 ± 2.06	1.1 ± 0.026

Note: *** the particular test not carried out for stavudine.

spherical. The surface of the drug-loaded microspheres manifested the presence of drug particles (see **Fig. 1**). The spherical nature and size of the microspheres did not change after the dissolution tests, but the number of pores increased. When a cross section of the microspheres were viewed it showed a spongy appearance.

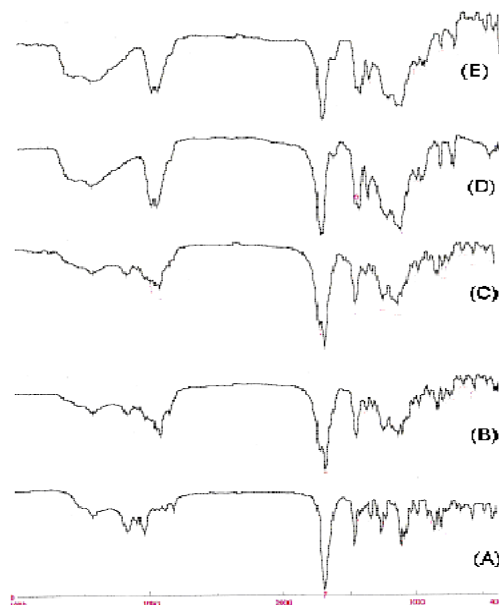
Fourier Infrared Spectroscopy (FTIR)

As shown in **Fig. 2**, there was no significant difference in the IR spectra of pure stavudine and drug-loaded microspheres (Both Eudragit RS and RS: RL loaded microspheres). The characteristic OH stretching, NH stretching of secondary amine, C-H stretching and C=O stretching of pure drug was unchanged in case of microspheres. The results suggest drug stability during the encapsulation process. This was further supported by the DSC results that follow.

Differential Scanning Calorimetry (DSC)

The drug may have been dispersed in crystalline or amorphous form or dissolved in the polymeric matrix during formation of the microspheres. Any abrupt or drastic change in the thermal behavior of either the drug or polymer may indicate a possible drug-polymer interaction^{11, 12}. The thermo-gram of pure

correspond to its melting point (161^o C to 167^o C). This endotherm was also observed for Eudragit RS100 microspheres at 160^o C but it was less sharp and this suggests that there is a significant reduction in drug crystallinity in the polymer matrix.



Wave number (Cm-1)

Fig. 2. FTIR Spectra of pure Stavudine (A), Eudragit RS loaded microspheres (B), Eudragit RS: RL loaded Microspheres (C), Eudragit RS blank Microspheres (D), Eudragit RS: RL blank Microspheres (E).

X-ray Powder Diffractometry (X-RPD)

The X-ray powder diffraction patterns of pure drug, RS and RS: RL microspheres containing stavudine reveals that the intensity of the peaks for the pure drug was sharp. But when it was incorporated into the polymer matrix, the drug peaks showed a loss of sharpness due probably decreased crystallinity of the drug.

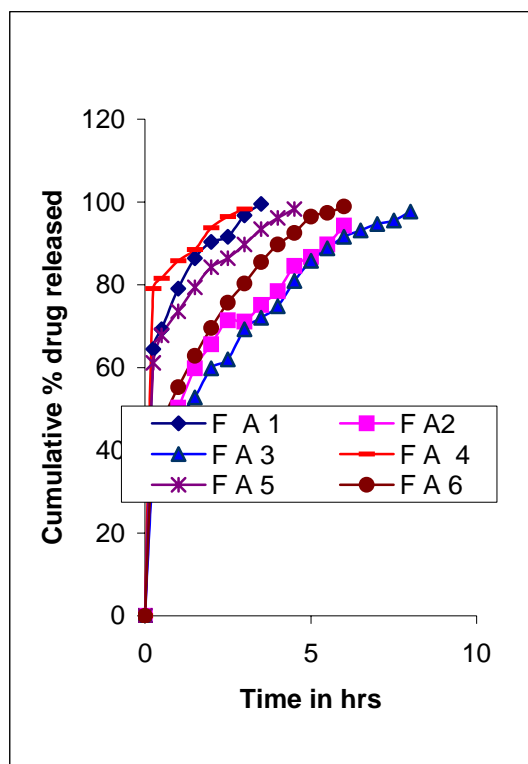


Fig.3. Cumulative percent release of Stavudine (n=3) from different microspheres prepared with different drug: polymer ratio.

Drug release behavior

The pure stavudine showed a fast release as 98 % was released within 7 min. When it was encapsulated, sustained release up to 8 h was observed. For FA₃, it was found that the release rate of drug from size fractions of 355 and 250 μm was faster than that of 500 μm. This is because the smaller the particle size the larger the surface area available for drug release. The drug release from formulation containing

Eudragit RS only was slow, but when RL was used in combination with RS, stavudine release from micro spheres was faster that is: FA₄ > FA₁, FA₅ > FA₂ and FA₆ > FA₃ (see fig. 3). This is due to the fact that the amount of quaternary ammonium groups of Eudragit RS is lower than that of Eudragit RL, which renders Eudragit RS is less permeable. It was also found that as the proportion of Eudragit RS was increased relative to drug concentration, the release rate of stavudine was decreased due to slower rate of diffusion through the polymer matrix.

Release Kinetics

The release mechanism of stavudine from various formulations was determined by comparing their respective correlation coefficient (see Table 2.). It would appear that the mechanism of drug release from microspheres was diffusion-controlled. When the release rate constants of stavudine microspheres were compared, it was found to follow the following order: FA₄ > FA₁ > FA₅ > FA₆ > FA₂ > FA₃.

CONCLUSION

Stavudine microspheres was prepared successfully using the solvent evaporation method. Polymer: drug ratio, stirring speed and the content of magnesium stearate influenced the sphericity of the microspheres. The yield and entrapment efficiency were high for all formulations. It was observed that with increase in polymer concentration, the mean particle size of the microspheres increased but increasing the stirring speed and magnesium stearate content, resulted in a decrease in the mean particle size of microspheres. The assessment of the release kinetics revealed that drug release from stavudine microspheres followed Higuchi Model. It was suggested that mechanism of drug release from microspheres was diffusion-controlled. Controlled release without initial peak level achieved with these formulations may reduce dose frequency and side effects as well as improve patient compliance.

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References

1. Tomofumi Yamuda, Hiraku Onishi, Yoshiharu Machida, Sustained release kitoprofen microparticles with ethyl cellulose and carboxymethyl ethyl cellulose. *Journal of controlled Release*. 2001; 75: 271-282.
2. Goodman S, Gilman A. *The Pharmacological Basis of Therapeutics*, New York, NY: Macmillan Publishing company; 1985.
3. Jung-Hwa lee, Tae Gwan Park and Hoo-kyan choi. Effect of formulation and processing variable on the characteristics of microspheres for water soluble drugs prepared by w/o/o double emulsion solvent diffusion method. *International journal of pharmaceutics*. 2000; 196:75-78.
4. Chowdary K.P.R., Koteshwara Rao N, and Malathi K. Ethyl cellulose microspheres of gliplizide: characterization, *in vitro* and *in vivo* evaluation. *Indian Journal of pharmaceutical sciences*. 2004; 66 (4): 412- 416.
5. S. Hazedar, B.Dortunc. Preparation and *in vitro* evaluation of eudragit microspheres containing acetazolamide. *International journal of pharmaceutics*. 2004; 269: 131-140.
6. Pralhad T.Tayade, and Rajendra Kumar D.Kale. Encapsulation of water – insoluble Drug by a cross-linking Technique: Effect of process and formulation variables on encapsulation efficiency, particle size, and *In vitro* Dissolution Rate. *AAPS Pharma Sci Tech*. 2004; 6(1) Article 12.
7. Badri Viswanathan N, Thomas P.A, Pandit J.K, Kulkarni M.G and Mashelkar R.A. Preparation of non-porous microspheres with high entrapment of proteins by a (water-in-oil) –in –oil emulsion technique. *Journal of controlled release*. 1999; 58: 9-20.
8. Barkai A, Pathak V, Benita S. Polyacrylate (Eudragit retard) microspheres for oral controlled release of nifedipine. I. Formulation design and process optimization. *Drug Dev Ind Pharm*. 1990; 16: 2057-2075.
9. Kawashia Y, Niwa T, Takeuchi H, Hino T, Itoh Y, Furuyamas. Characterization of polymorphs of tranilast anhydrate and tranilast monohydrate when crystallized by two solvent change spherical crystallization techniques. *J Pharma Sci*. 1991; 81: 472–478.
10. Costa P and Lobo J.M.S. Modeling and comparison of dissolution Profiles. *European Journal of pharmaceutical Sciences*. 2001; 13:123 -133.
11. Bodmeier R, Chen H. Preparation and characterization of microspheres containing the anti-inflammatory agents, Indomethacin, ibuprofen and kitoprofen. *J. Controlled Release*. 1989; 10: 167-175.
12. Jones DS, Pearce KJ, Investigation of the effects of some process variables on microencapsulation of propranolol HCl by solvent evaporation method. *Int J Pharm*. 1995; 118: 99 -2005.