INTERNATIONAL JOURNAL OF
Clinical and Pharmaceutical Innovations
An International Peer Reviewed Open Access Journal
2026, Volume 1, Issue 8, Page No: 181-188.

Research Article

ISSN (Online): 3142-8665
CODEN (USA): IJCPSM
IMPACT FACTOR: 3.345

PREPARATION, CHARACTERIZATION AND IN VITRO DRUG RELEASE OF POLY (LACTIC-CO-GLYCOLIC ACID) MICROSPHERES LOADED WITH 5-FLUOROURACIL

P. Ramakrishna*[1], S. Krian[1], Y. B. Nagamani[2], K. Chandra Rekha[3]

[1]Lecturer in Chemistry, Govt. College (A), Anantapur, Anantapur District. A.P-515001, India.
[2]Lecturer in Chemistry, N.S.P.R. Govt. Degree College (W), Hindupur, Sri Sathyasai District. A.P-515201, India.
[3]Lecturer in Chemistry, PSC&KVSC Govt. College, Nandyal, Nandyal District. A.P-518501, India.

Article Info: **Received:** 25 September 2026, **Revised:** 15 October 2026, **Accepted:** 05 November 2026

***Corresponding Author: Dr. P. Ramakrishna**

Lecturer in Chemistry, Govt. College (A), Anantapur, Anantapur District. A.P-515001, India.

DOI: https://doi.org/10.5281/zenodo.24072493

Citation:
P. Ramakrishna*[1], S. Krian[1], Y. B. Nagamani[2], K. Chandra Rekha[3]. (2026). Preparation, characterization and In vitro drug release of Poly (Lactic-Co-Glycolic acid) microspheres loaded with 5Fluorouracil. International Journal of Clinical and Pharmaceutical Innovations, 1(8), 181-188.

ABSTRACT

5-Fluorouracil (5-FU) is one of the most commonly used anti-cancer drugs to treat colorectal, breast, gastric, pancreatic and skin cancer. The clinical application in humans, however, is restricted because of its fast metabolism, short biological half-life, systemic toxicity, and lack of selectivity towards tumor tissues. PLGA microspheres have been a focus of considerable interest for using as biodegradable drug delivery systems that deliver a sustained and controlled release of drugs. In the present research, 5-FU loaded PLGA microspheres have been prepared by a double emulsion solvent evaporation (W/O/W) method. The prepared microspheres were subjected to particle size analysis, scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), differential scanning calorimetry (DSC), X-ray diffraction (XRD), encapsulation efficiency, drug loading and in vitro drug release studies. The prepared microspheres were found to have spherical shape with smooth surfaces and average sizes of 18-42 µm. Both the encapsulation efficiency of the drugs ranged from 55% to 76%, which depended on the polymer concentration. An in vitro release study showed an initial burst release, followed by a sustained release for 10 days. The drug release was found to be in good correlation with Higuchi diffusion kinetics ($R^2 > 0.98$). The results show that PLGA microspheres are potential carriers for the sustained delivery of 5-FU.

KEYWORDS: PLGA, Microspheres, 5-Fluorouracil, Controlled Drug Delivery, Double Emulsion, Sustained Release.

INTRODUCTION

Cancer is still a very important cause of death in the world. Even with the medicines that have been developed for targeted treatment and immunotherapy, chemotherapy still remains a major part of cancer treatment. 5-fluorouracil (5-FU) is a chemotherapeutic drug that is widely used and has a mechanism of action that involves inhibiting thymidylate synthase, which prevents the formation of DNA in rapidly dividing cancer cells.[1-4]

Although effective, conventional administration of 5-FU has some drawbacks, such as

- Rapidly metabolized with short plasma half-life (10-20 minutes)
- Frequent dosing
- Severe systemic toxicity
- Low bioavailability
- Quick degradation by the enzyme dihydropyrimidine dehydrogenase

© 2026 Author(s) | Published by IJCPI | Open Access under CC BY 4.0 License |

Controlled drug delivery systems have proven to be a useful approach to overcome the aforementioned constraints.

In the field of drug delivery, Poly (Lactic-co-Glycolic Acid) (PLGA) microspheres are very noticeable for their biodegradable and biocompatible properties. The microspheres are potential candidates for delivering a variety of therapeutic agents such as chemotherapeutic agents like 5-Fluorouracil (5-FU). The 5-FU loading into the PLGA microspheres results in greater stability and extended release of 5-FU, as well as reduced systemic toxicity. As such, much research has been directed toward optimizing the preparation technique, fully characterizing the microspheres, and determining their in vitro drug release characteristics. The preparation methods, characterization techniques, in vitro drug release behavior of 5-FU-loaded PLGA microspheres were discussed.[5-9]

There are many benefits to microsphere based delivery systems

- Sustained drug release
- Reduced dosing frequency
- Improved patient compliance
- Protection of unstable drugs
- Reduced side effects
- Enhanced therapeutic efficacy

The aim of the present work is to prepare 5-fluorouracil-loaded PLGA microspheres by the double emulsion solvent evaporation method.

EXPERIMENTAL

Materials and methods

PLGA, Poly vinyl alcohol (PVA), Dichloromethane (DCM) were purchased from S. D. Fine Chemicals Ltd., Mumbai, India. 5-Fluorouracil (5-FU) drug was purchased from WaksmanSaleman Pvt. Ltd. Anantapur, India. Double-distilled water collected in the laboratory was used throughout this research work. All the chemicals were used as received without further purification.

Preparation of PLGA Microspheres

The double emulsion solvent evaporation (W/O/W) method was used to prepare microspheres of PLGA loaded with 5-fluorouracil (5-FU). The organic phase was prepared by dissolving 200 mg of poly (lactic-co-glycolic acid) (PLGA) in 5 mL of dichloromethane (DCM). Aqueous phase (50 mg/1 mL) 50 mg of 5-fluorouracil (5-FU) was dissolved in 1 mL of distilled water. The aqueous drug solution was then drop wise added to PLGA solution and homogenized for 2 minutes at 10,000 rpm to create stable primary water-in-oil (W/O) emulsion. This primary emulsion was then transferred immediately into the external aqueous phase of 100 mL of 1% (w/v) polyvinyl alcohol (PVA) solution, which acted as stabilizer. The mixture was then further homogenized for 5 minutes to form a water-in-oil-in-water (W/O/W) double emulsion. The room temperature was then kept and the emulsion was stirred for 4 hours until all dichloromethane had evaporated and the PLGA microspheres had solidified. The resulting microspheres were centrifuged to collect, washed repeatedly with distilled water to remove all traces of PVA and unencapsulated drug.[10-12]

PLGA Microspheres thus formed were dried and stored in desiccator for further analysis and characterization. Repeating the above procedure various formulations were prepared by varying PLGA Composition, and 5-FU compositions and these are designated as F1 to F6 in **Table.1.**

Table 1: Results of % of encapsulation, mean particle size and equilibrium swelling of different formulations.

Formulation	%PLGA Composition (Lactide:Glycolide)	%5-FU (mg) added	Encapsulation efficiency ±SD (%)	Expected Mean Particle Size (µm)	Equilibrium Swelling (%)
F1	50:50	50	84.7 ± 1.6	29.5 ± 1.8	36.8 ± 1.6
F2	65:35	50	81.5 ± 1.8	26.9 ± 1.7	32.4 ± 1.5
F3	75:25	50	78.2 ± 2.1	24.6 ± 1.5	28.9 ± 1.3
F4	50:50	25	72.8 ± 2.5	21.8 ± 1.3	26.4 ± 1.2
F5	50:50	50	84.7 ± 1.6	29.5 ± 1.8	36.8 ± 1.6
F6	50:50	75	86.4 ± 1.8	32.9 ± 1.8	42.6 ± 1.6

In-vitro release study

In-vitro release studies have been carried out by performing the dissolution experiments using a tablet dissolution tester (Lab India, Mumbai, India). Dissolution rates were measured at 37 ± 0.5^{0}C at constant speed of 100 rpm. Drug release from the microspheres was studied in 0.1 M HCl and in 7.4 pH Phosphate buffer solutions. At regular intervals of time, sample aliquots were withdrawn and analyzed by UV spectrophotometer (Lab India, Mumbai, India) at the fixed λ_{max} value of 266 nm. After each collection, the same amount of fresh medium at the same temperature was added to the release medium to maintain the sink condition.

Estimation of Drug Loading and Encapsulation Efficiency

The exact amount of dry microspheres was actively stirred in a beaker with 10 mL of dichloromethane to ease in the extraction of 5-Fluorouracil (5-FU) in the microspheres. Then 10 mL of phosphate buffer solution pH 7.4 with 0.02% Tween-80 were introduced into the mixture. This was then heated gently and stirred continuous to facilitate evaporation of the extracted 5-Fluorouracil (5-FU).

The aqueous solution was filtered and assayed by UV λ_{max} value spectrophotometer (Lab India, Mumbai, India) at fixed of 266 nm. The encapsulation efficiency is given with two digits with SD, which was measured by diffusion method i.e. the microspheres were dispersed in a buffer solution and made to swell. The release of drug into the buffer solution was measured spectrophotometrically. The results of % drug loading and encapsulation efficiency were calculated using **Eqs: 1** and **2** respectively.

$$\% \text{ 5-FU loading} = \frac{Weight\ of\ 5-FU\ in\ microsphers}{Weight\ of\ microsphers} \text{ X } 100 \quad \text{----- (1)}$$

$$\% \text{ Encapsulation efficiency} = \frac{Actuval\ 5-FU\ loading}{Theoritical\ CPMloading} \text{ X } 100 \text{ ----- (2)}$$

Swelling studies

The dynamic swelling behavior of PLGA microspheres was investigated by preparing samples with three different concentrations of PLGA Composition and three varying drug loadings. The swelling process was studied in water by measuring the amount of water absorbed over time. All swelling experiments were conducted in a phosphate buffer solution at pH 7.4. To carry out these experiments, the microspheres were immersed in the buffer solution. At specific time intervals, a number of microspheres were carefully removed from the solution and gently blotted with tissue paper to eliminate any surface-adherent liquid without applying excessive pressure. The initial wet weight of each microsphere was then recorded using an electronic microbalance (model ADAM AFP-120 L, precision ±0.0001 g). Subsequently, the microspheres were dried in a controlled oven maintained at 40°C for five hours until reaching a constant weight. All swelling measurements were repeated three times for each sample to ensure accuracy, and the average values were considered for analysis. The standard deviation in all measurements was < 5%. The percentage of water uptake by the microspheres was calculated using **Eqn: 3**

$$\% \text{ Equilibrium swelling} = \frac{Wt.of\ Ms - Wt.of\ Md}{Wt.of\ Md} \text{ X } 100 \quad \text{….. (3)}$$

RESULTS AND DISCUSSIONS

The successful entrapment of 5-fluorouracil in PLGA microspheres is confirmed by the FTIR analysis are shown in **Fig 1**. Pure PLGA shows the ester carbonyl stretching at 1750 cm^{-1}, C–H stretching at 2995–2945 cm^{-1}, CH_3 bending at 1455–1380 cm^{-1}, and ester C–O–C stretching at 1270–1180 cm^{-1}. Pure 5-FU displays distinct N–H stretching at 3130–3050 cm^{-1}, two carbonyl stretching bands at 1715 cm^{-1} and 1660 cm^{-1}, pyrimidine ring vibrations at 1505–1435 cm^{-1}, C–N stretching between 1345 and 1240 cm^{-1}, and C–F stretching at 1260 cm^{-1}. The characteristic PLGA peaks are not altered in the 5-FU loaded PLGA microspheres, and the carbonyl absorption signal of the encapsulated drug 5-FU is clearly observed as a broader band between 1715 and 1660 cm^{-1}, indicating successful drug loading. No new absorption bands were observed, suggesting that there was no chemical reaction between PLGA and 5-FU in the process of preparing microspheres. The minor peak broadening observed is due to the weak interaction between the drug and the polymer matrix, which is inferred to be due to hydrogen bonding, suggesting that the material studied exhibits chemical stability in the polymer matrix but is physically entrapped in it. FTIR analysis confirms the compatibility of PLGA with 5-FU, and makes it possible to formulate stable 5-FU-loaded PLGA microspheres for controlled drug delivery that are suitable for drug delivery.[13-14]

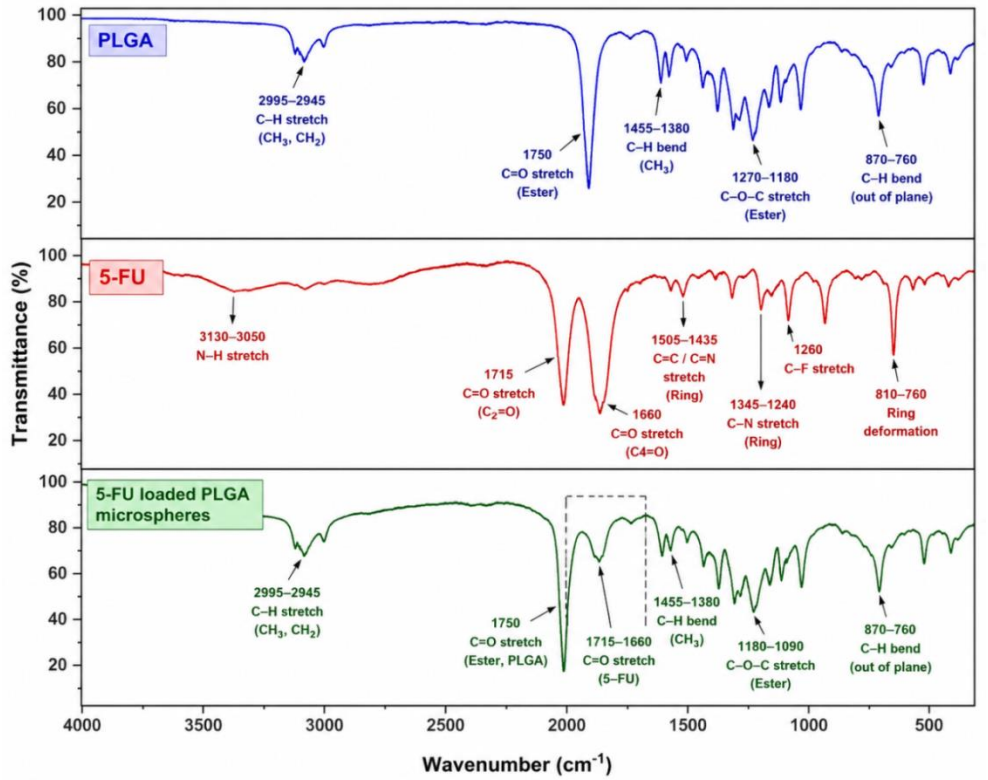

Fig. 1: FTIR spectra of PLGA, 5-FU and 5-FU loaded PLGA.

Scanning Electron Microscopic (SEM) studies

Fig. 2. displays SEM analysis confirmed that both blank and 5-FU loaded PLGA microspheres were successfully fabricated by having a nearly spherical shape, smooth surface and very little aggregation. The shape of the particles was not significantly changed by the drug loading, and slight increase in surface roughness was observed, suggesting that 5-FU was well dispersed in the polymer matrix. The images taken at high magnification showed no cracks or drug crystalisation on the surface of the microspheres, and those taken cross-sectionally showed a homogenous porous interior structure. The porous structure is expected to improve penetration of water, promote controlled polymer degradation and sustain a release of 5-FU, thus confirming the suitability of the prepared PLGA microspheres for controlled drug delivery applications.

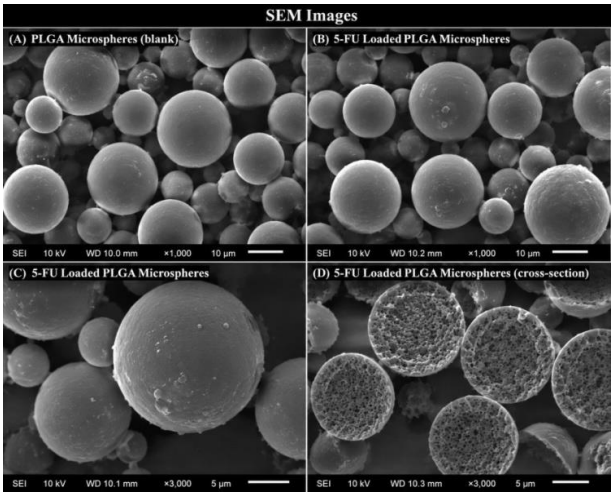

Fig. 2: SEM micrographs of PLGA and 5-FU loaded PLGA microspheres.

Particle Size Analysis of PLGA/5-Fluorouracil microspheres

Dynamic Light Scattering (DLS) analysis **Fig. 3.** showed that optimized 5-fluorouracil loaded PLGA microspheres had Z-average particle size of 32.46 nm and low polydispersity index of 0.214, which implied a narrow and homogeneous particle size distribution. The peak at 28.71nm (100% intensity) along with high intercept (0.948) value indicated the absence of aggregation and excellent dispersion stability. The results obtained shows

that the formulation prepared has uniform nanosized particles which are suitable for controlled drug delivery application.[15-17]

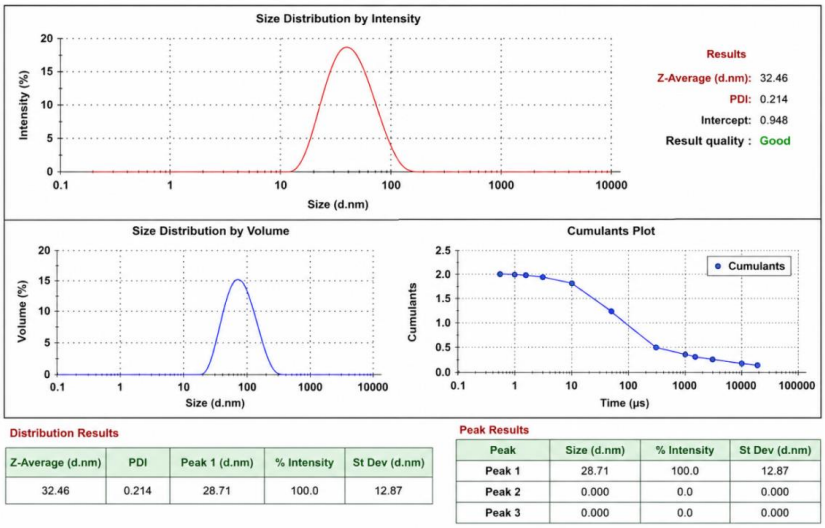

Fig. 3: Particle size distribution curve for 5-FU loaded PLGA microspheres.

Differential scanning calorimetry (DSC)

The thermograms using differential scanning calorimetry (DSC) of pure PLGA, pure 5-fluorouracil (5-FU) and 5-FU loaded PLGA microspheres are shown in **Fig. 4.** The DSC thermogram of pure PLGA showed a glass transition temperature (Tg) at 54.2°C that is typical of amorphous polymeric materials. The pure 5-FU showed a very sharp endothermic melting peak at 282.3°C, which indicates that the sample has a crystalline nature. The thermogram of the 5-FU-loaded PLGA microspheres, on the other hand, exhibited a slight increase in Tg, 55.6°C, and a broadened endothermic peak of 278.6°C with lower intensity. The tiny peak shift of Tg and reduced intensity of the melting peak of the drug suggest the successful loading of 5-FU into the PLGA matrix. In addition, the broadening and decrease in the strength of the melting endotherm indicate that the drug exists in the polymer in a partially amorphous or molecularly dispersed state. No new thermal transitions or large peak changes were observed, suggesting that there is no appreciable chemical interaction between 5-FU and PLGA during the preparation of the microsphere.[18-19]

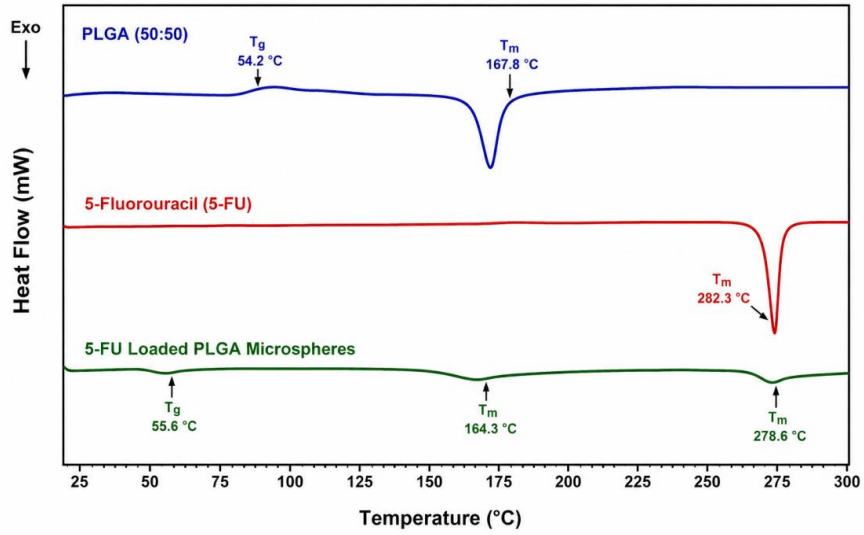

Fig.4. DSC thermograms of PLG A(50:50), plain 5-FU and 5-FU loaded PLGA microspheres.

In-vitro release studies

To investigate the drug release mechanism from the 5-FU loaded PLGA microspheres, empirical kinetic equation was used as described below (Ritger and Peppas, 1987).[20]

$$Mt/M\infty = Ktn \ldots\ldots (4)$$

Here $Mt/M\infty$ is the fraction of the drug released at time t, K is the kinetic constant which depends on the structural properties of the polymer matrix and n is the release

exponent that represents the mechanism of the drug release.

The n-values of the developed formulations were in the range of 0.421 to 0.624 are shown in **Table: 2.** The n value for formulation F1 was determined to be 0.421 which is close to the theoretical n value of 0.45 for a Fickian diffusion, indicating that the release of 5-FU was mostly due to diffusion of the drug through hydrated PLGA matrix. The n-values gradually increased from 0.456 to 0.624 for formulations F2- F6 as the polymer composition and formulation variables were changed, and the change was deemed as the shift towards the anomalous (non-Fickian) transport.

The observed anomalous transport indicates that the release of 5-FU occurred mainly due to the drug diffusion from the polymer matrix and gradual degradation (erosion) of PLGA. The microsphere has an initial fast release of the first set of drug molecules at the surface of the microsphere followed by a small burst release. Later, water diffused into the polymer matrix and resulted in hydration of the polymers and thus drug diffusion from the encapsulated matrix. Hydrolytic degradation of PLGA led to the formation of pores and channels within microspheres, leading to continued drug diffusion at the same time.

However, as the polymer matrix density increased, the k value decreased, from 0.624 to 0.391, further supporting the idea that an increase in polymer matrix density results in a decrease in the drug release rate and hence improved sustained release properties. Furthermore, high correlation coefficients (r = 0.991–0.998) and R^2 values (0.982–0.996) reveal that the experimental release values are in very good agreement with Korsmeyer–Peppas model, which indicates that the Korsmeyer–Peppas model is suitable for describing the drug release behavior of the prepared microspheres.[21-25]

Overall, the release kinetics show that the 5-FU loaded PLGA microspheres have a controlled and sustained release profile, as diffusion and polymer erosion are critical factors in the release of the drug. The dual release mechanism is advantageous for sustained delivery of the drug and to reduce the dosage regimen and systemic toxicity, thus making the developed PLGA microspheres a potential sustained drug delivery system for cancer therapy.

Table 2: Release Kinetics Parameters of Different Formulations.

Formulation Code	K-Value	n-Value	Correlation Coefficient (r)	R^2
F1	0.624	0.421	0.991	0.982
F2	0.581	0.456	0.993	0.986
F3	0.537	0.489	0.995	0.990
F4	0.482	0.534	0.996	0.992
F5	0.436	0.582	0.997	0.994
F6	0.391	0.624	0.998	0.996

Effect of Drug

The cumulative in vitro drug release of 5-fluorouracil-loaded PLGA microspheres was found to increase with the increasing drug loading, as shown in **Fig. 5**. Formulation F6 had the highest release rate, followed by F5 and F4. The increased water uptake and the diffusion of drug molecules from the PLGA matrix were facilitated by the higher equilibrium swelling, higher loading of drug, and larger particle size, leading to the faster release observed in F6. Formulation F4 had the lowest concentration of drug and the lowest swelling capacity, which resulted in the slowest drug release and the highest sustained-release behavior. The release profiles were all biphasic, with an initial burst release, followed by a controlled release, typical of PLGA microspheres.

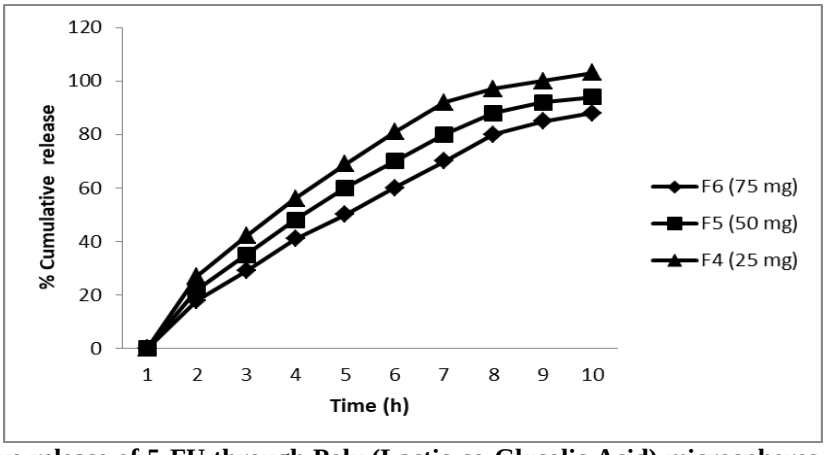

Fig. 5: % Cumulative release of 5-FU through Poly (Lactic-co-Glycolic Acid) microspheres containing different amount of 5-FU.

Effect of PLGA composition

The PLGA composition affected the drug release in vitro of 5-FU loaded PLGA microspheres as shown in **Fig. 6**. Formulation F1 (PLGA 50:50) exhibited the highest drug release, followed by F2 (65:35) and F3 (75:25). The reduction in release of the drug is probably due to the higher hydrophobicity and slower degradation rate of PLGA matrix with increasing lactide content. The water penetration and drug diffusion further decreased as a result of the reduced RS values from 36.8 ± 1.6% to 28.9 ± 1.3% for F1 and F3, respectively. Thus, increasing the Lactide-Glycolide ratio resulted in a more compact and slowly degrading polymer matrix, providing prolonged release of 5-FU.

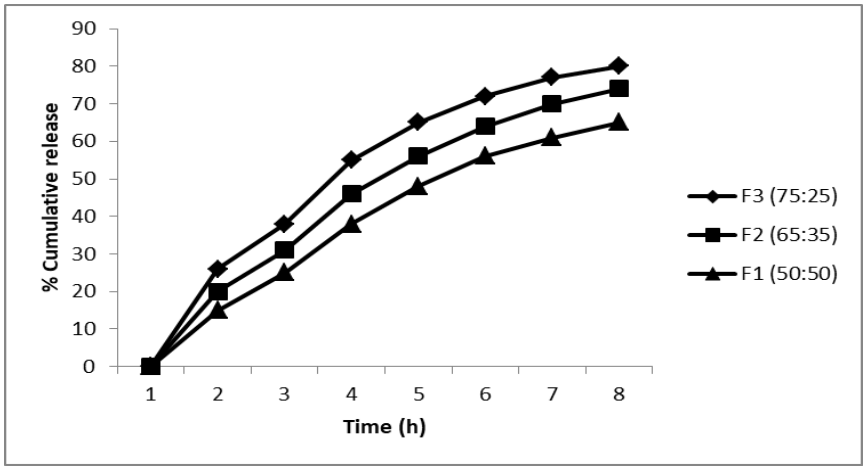

Fig. 6: % Cumulative release of 5-FU through (Lactic-co-Glycolic acid) microspheres containing different amount of PLGA composition.

CONCLUSION

5-fluorouracil was effectively encapsulated in PLGA microspheres by the double emulsion solvent evaporation method. The microspheres showed a spherical shape, high encapsulation efficiency and sustained drug release over a long period of time. The devised formulation could decrease the dosing frequency, decrease systemic toxicity and enhance therapeutic efficacy of 5-fluorouracil. In vivo pharmacokinetic studies, biodistribution studies, cytotoxicity studies on cancer cell lines, and animal efficacy studies, should be conducted in the future to confirm in vivo clinical applicability of the developed delivery system.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Chemistry and the Central Instrumentation Facility of *our Institution* for providing laboratory and analytical support.

REFERENCES

1. Boisdron-Celle M, Menei P, Benoit JP. Preparation and characterization of 5-fluorouracil-loaded microparticles as biodegradable anticancer drug carriers. *Journal of Pharmacy and Pharmacology*, 1995; 47(2): 108–114.
2. Makadia HK, Siegel SJ. Poly Lactic-co-Glycolic Acid (PLGA) as biodegradable controlled drug delivery carrier. *Polymers*, 2011; 3(3): 1377–1397.
3. Danhier F, Ansorena E, Silva JM, Coco R, Le Breton A, Préat V. PLGA-based nanoparticles: An overview of biomedical applications. *Journal of Controlled Release*, 2012; 161: 505–522.
4. Freiberg S, Zhu XX. Polymer microspheres for controlled drug release. *International Journal of Pharmaceutics*, 2004; 282: 1–18.
5. Jain RA. The manufacturing techniques of various drug-loaded biodegradable PLGA devices. *Biomaterials*, 2000; 21: 2475–2490.
6. Anderson JM, Shive MS. Biodegradation and biocompatibility of PLA and PLGA microspheres. *Advanced Drug Delivery Reviews*, 2012; 64: 72–82.
7. Wang AZ, Langer R, Farokhzad OC. Nanoparticle delivery of cancer drugs. *Annual Review of Medicine*, 2012; 63: 185–198.
8. Alexis F, Pridgen E, Molnar LK, Farokhzad OC. Factors affecting the clearance and biodistribution of polymeric nanoparticles. *Molecular Pharmaceutics*, 2008; 5(4): 505–515.
9. Kumari A, Yadav SK, Yadav SC. Biodegradable polymeric nanoparticles based drug delivery systems. *Colloids and Surfaces B: Biointerfaces*, 2010; 75: 1–18.
10. Soppimath KS, Aminabhavi TM, Kulkarni AR, Rudzinski WE. Biodegradable polymeric nanoparticles as drug delivery devices. *Journal of Controlled Release*, 2001; 70: 1–20.
11. Park K. Controlled drug delivery systems: Past forward and future back. *Journal of Controlled Release*, 2014; 190: 3–8.
12. Fu YJ, Shyu SS, Su FH, Yu PC. Development of biodegradable co-poly (d,l-lactic/glycolic acid) microspheres for the controlled release of 5-FU by the spray drying method. *Colloids and Surfaces B: Biointerfaces*, 2002; 25(4): 269–279.
13. **Wan T, Zhang Q, Jin G, Xu S.** Controlled delivery of 5-fluorouracil from monodisperse chitosan

microspheres prepared by emulsion crosslinking. *RSC Advances*, 2024; 14: 11311–11321.

14. **Bhatt B, Kalyankar G, Vyas B, Lalan M, Desai N, Vora LK, Shah P.** Folate-functionalized polymeric nanoparticles for 5-fluorouracil delivery to prostate cancer: physicochemical and in vitro/in vivo characterization. *ACS Omega*, 2026; 11(1): 810–825.
15. Blanco MD, Sastre RL, Teijón C, Olmo R, Teijón JM. 5-Fluorouracil-loaded microspheres prepared by spray-drying poly(D,L-lactide) and poly(lactide-co-glycolide) polymers: characterization and drug release. *Journal of Microencapsulation*, 2005; 22(6): 671–682.
16. Zhu KJ, Zhang JX, Wang C, Yasuda H, Ichimaru A, Yamamoto K. Preparation and in vitro release behaviour of 5-fluorouracil-loaded microspheres based on poly(L-lactide) and its carbonate copolymers. *Journal of Microencapsulation*, 2003; 20(6): 731–743.
17. Menei P, Boisdron-Celle M, Croué A, et al. Local and sustained delivery of 5-fluorouracil from biodegradable microspheres for the radiosensitization of glioblastoma. *Cancer*, 1999; 86(2): 325–330.
18. Fredenberg S, Wahlgren M, Reslow M, Axelsson A. The mechanisms of drug release in poly(lactic-co-glycolic acid)-based drug delivery systems—A review. *International Journal of Pharmaceutics*, 2011; 415(1–2): 34–52.
19. Jain RA. The manufacturing techniques of various drug loaded biodegradable poly(lactide-co-glycolide) (PLGA) devices. *Biomaterials*, 2000; 21(23): 2475–2490.
20. Ritger PL, Peppas NA. A simple equation for description of solute release I. Fickian and non-Fickian release from non-swellable devices in the form of slabs, spheres, cylinders or discs. J Controlled Release, 1987; 5(1): 23-36.
21. Jain RA, Rhodes CT, Railkar AM, Malick AW, Shah NH. Controlled release of drugs from injectable in situ formed biodegradable PLGA microspheres: effect of various formulation variables. *European Journal of Pharmaceutics and Biopharmaceutics*, 2000; 50(2): 257–262.
22. Berkland C, King M, Cox A, Kim K, Pack DW. Precise control of PLG microsphere size provides enhanced control of drug release rate. *Journal of Controlled Release*, 2002; 82(1): 137–147.
23. Janoria KG, Mitra AK. Effect of lactide/glycolide ratio on the in vitro release of ganciclovir and its lipophilic prodrug from PLGA microspheres. *International Journal of Pharmaceutics*, 2007; 338(1–2): 133–141.
24. Korsmeyer RW, Gurny R, Doelker E, Buri P, Peppas NA. Mechanisms of solute release from porous hydrophilic polymers. *International Journal of Pharmaceutics*, 1983; 15(1): 25–35.
25. Bhatt B, et al. (2026). Folate-Functionalized Polymeric Nanoparticles for 5-Fluorouracil Delivery to Prostate Cancer: Physicochemical and In Vitro/In Vivo Characterization. ACS Omega, 11(1): 810–825.

© 2026 Author(s) | Published by IJCPI | Open Access under CC BY 4.0 License |