Original Article

FORMULATION AND EVALUATION OF FLOATING MICROSPHERES OF CIPROFLOXACIN BY SOLVENT EVAPORATION METHOD USING DIFFERENT POLYMERS

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ABSTRACT

Objective: The main intention of this research was to formulate and evaluate floating microspheres of ciprofloxacin using different polymers to prolong gastric residence time.

Methods: The microspheres were formulated by the solvent evaporation method using different ratios of polymers like carbopol 940, ethylcellulose, and Hydroxy Propyl Methyl Cellulose K4M. Further, the floating microspheres were evaluated for micromeritic properties like bulk density, tapped density, angle of repose, etc., percentage yield, particle size, entrapment efficiency, floating capacity, *in vitro* drug release study, release kinetics, drug content, swelling index, and Fourier Transform Infrared Spectroscopy (FTIR) (Compatibility studies).

Results: The ciprofloxacin microspheres showed the good flowing property. The particle size ranged from 258.1±2.21 μm to 278±2.86 μm and entrapment efficiency ranged from 63.17±0.43% to 89.90±1.32%. The IR spectrum revealed that there was no interaction between the drug and polymer. F7 formulation was found to be the best formulation. Drug release was found to be 90.70±0.89% i.e. in a controlled manner at the end of 10 h.

Conclusion: The floating microspheres were prepared successfully and the results clearly stated that prepared ciprofloxacin microspheres may be safe and effective controlled drug delivery over an extended period which can increase bioavailability, patient compliance, and decrease dosing frequency.

Keywords: Ciprofloxacin, Solvent evaporation method, Carbopol 940, Ethylcellulose, Hydroxy propyl methyl cellulose K4M, Floating microspheres

INTRODUCTION

Oral route of administration is one of the most suitable and generally used method of drug administration and also the development of stomach specified oral controlled release drug delivery system is difficult due to the difference in pH in different sections of the gastrointestinal tract, the alteration in gastric emptying time and also the problem of localizing an oral delivery system in a selected location of the gastrointestinal tract. Rapid gastrointestinal transit can prevent the absorption of the complete drug within the absorption zone and decrease the efficacy of the administered dose of the drug since most of the drugs are absorbed in the stomach or the upper part of the small intestine. To control the above-discussed problems so many types of oral controlled drug delivery systems having prolonged gastric residence time have been outlined such as floating drug systems, swelling or expanding systems, mucoadhesive systems, modified-shape systems, high-density systems, and more delayed gastric emptying devices [1]. Gastroretentive delivery systems are mainly designed for drugs that have a narrow absorption window. Such systems get retain at the site of absorption and release the drug in a controlled manner for a longer time. The floating drug delivery system has drawn much attention nowadays due to buoyancy action having greater safety for clinical uses and having no effect on the peristaltic movement of the GIT. Drugs that have a short half-life require frequent dosing as they get eliminated quickly from blood circulation therefore to increase the bioavailability of such drugs controlled-release formulations are prepared [2].

Floating microspheres are gastro retentive drug delivery system based on non-effervescent phenomena. It can be also known as hollow microspheres, micro-balloons, or floating micro-particles. Microspheres are spherical empty particles that don't have a core. These microspheres are free-flowing particles that have a size ranging from 1-1000 μm [3]. Ciprofloxacin is an antibiotic, which belongs to the fluoroquinolone category and is a broad-spectrum second-generation antibacterial agent. It is widely used to treat urinary tract infections, gram-negative bacterial infections, ophthalmic, skin, bone, joint, respiratory, and intra-abdominal infections, periodontal pathogens, and bacterial diarrheal infections [4]. The structure of ciprofloxacin is shown in fig. 1. The present study has been done to formulate floating microspheres of ciprofloxacin with varying drug-polymer ratios. Ciprofloxacin floating microspheres were prepared to obtain prolonged or controlled drug delivery to improve bioavailability and to target drug at specific sites.
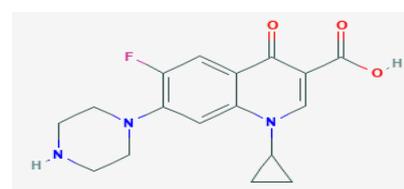
Fig. 1: Structure of ciprofloxacin

MATERIALS AND METHODS

Materials

Ciprofloxacin was obtained from Yarrow Chem Products. Carbopol 940, HPMC K4M were obtained from Research Lab Fine Chem Industries, Mumbai. Ethyl Cellulose was obtained from Loba Chemie Pvt. Ltd. Mumbai and Cosmo Chem. All other chemicals and reagents were of analytical grade which was used.

Methods

Calibration curve of ciprofloxacin

A stock solution of Ciprofloxacin was prepared by dissolving 100 mg of the drug in 100 ml of 0.1N Hydrochloric acid (HCl) to attain 1 mg/ml. From this stock solution, certain dilutions were made with

0.1N HCl to achieve certain series of standard solutions of concentration containing 1, 2, 3, 4, 5, 6µg/ml. The spectrum of standard solutions was run from the 200-400 nm range for determination of absorption maximum (λ max) [5, 6].

Drug-excipient compatibility study

Before preparation of floating microspheres, drug-excipient compatibility was studied using FT-IR spectrophotometer (FTIR-8400S Shimadzu) [7].

Preparation of floating microspheres by Solvent evaporation method

Floating Microspheres containing the antibiotic drug ciprofloxacin were prepared by a solvent evaporation method (table 1). In this technique, drug and polymer (HPMC K4M, carbopol 940, and Ethylcellulose) in various proportions were dissolved in a 20 ml acetone which was placed in a small beaker with a magnetic bead on the magnetic stirrer at room temperature. The drug-polymer mixture was poured into 30 ml liquid paraffin containing Tween 80 maintained at a temperature of 30-40 °C and subsequently stirred by the stirrer at ranging agitation speed i.e. 1200 rpm (revolution per minute) for 60 min to allow the volatile solvent to evaporate. The microspheres formed were filtered, washed with n-hexane and air-dried for 24 h, and stored in a desiccator [8, 9].

Characterization of floating microspheres

The following parameters were determined for the floating microspheres of Ciprofloxacin.

Table 1: Composition of ciprofloxacin floating microspheres

Formulation code	F1	F2	F3	F4	F5	F6	F7	F8	F9
Ciprofloxacin (mg)	100	100	100	100	100	100	100	100	100
Carbopol 940 (mg)	100	200	300	-	-	-	-	-	-
Ethylcellulose (mg)	-	-	-	100	200	300	-	-	-
HPMC K4 M (mg)	-	-	-	-	-	-	100	200	300
Acetone (ml)	20	20	20	20	20	20	20	20	20
Liquid Paraffin (ml)	30	30	30	30	30	30	30	30	30

Micromeritic properties

Bulk density

Bulk density is the ratio of the total mass of the powder to the bulk volume of powder. It is measured by pouring weighed microspheres of about 1g into a measuring cylinder and the bulk volume is noted down.

$$Bulk\ density = \frac{Weight\ of\ the\ powder}{Bulk\ Volume}$$

Tapped density

Tapped density is the ratio of the total mass of the powder to the tapped volume of the powder.

$$Tapped\ density = \frac{Weight\ of\ the\ powder}{Tapped\ volume}$$

Hausner's ratio

Hausner's ratio is the ratio of the tapped density to the bulk density.

Angle of repose

The angle of repose (θ) is used to measure the frictional forces in a loose powder [10].

$$\theta = \tan^{-1} h/r \text{ where h = height of the heap}$$

r = Radius of the heap.

% Compressibility index

The percentage compressibility index of powder is the measure of potential powder arch or bridge strength and stability. It can be calculated as per the following formula, [11].

$$Carr's\ Index = \frac{Tapped\ density - Bulk\ density}{Tapped\ density} X\ 100$$

Percentage yield

The percentage yield of the microspheres was determined by weighing the prepared microspheres of each formulation divided by the total amount of all non-volatile components which were used for the preparation of microspheres [12].

$$Percentage\ yield = \frac{Actual\ weight\ of\ product}{Total\ weight\ of\ drug\ and\ polymer} X\ 100$$

Particle size analysis

Particle size analysis of drug-loaded floating microspheres was performed by optical microscopy. Few microspheres were suspended in purified water (10 ml). The sample was placed on a clean glass slide and placed on a mechanical stage of the microscope. The eyepiece of the microscope fitted with a micrometer and the size of the spheres was determined [13].

Drug entrapment efficiency

The amount of drug entrapped was determined by crushing the microspheres in mortar and pestle. 50 mg was used for the evaluation. This was extracted with the aliquots of 0.1N hydrochloric acid (HCl). The extract was transferred to100 ml volumetric flask and the volume was made up with 0.1N HCl (pH-1.2). The solution was filtered and the absorbance was measured spectrophotometrically with suitable dilutions at a particular wavelength against the appropriate blank. The percent drug entrapped was calculated by the formula which is as follows: [14, 15]

$$\%\ Entrapment\ Efficiency = \frac{Practical\ Drug\ Content}{Theoretical\ Drug\ Content} X\ 100$$

Floating capacity

An *in vitro* study was carried out to determine floating capacity. 50 mg floating microspheres were placed in simulated gastric fluid (pH-1.2, 100 ml) containing tween 20 (0.02*w/v* %) and stirred on a magnetic stirrer at 100rpm. After 12h, the layer of buoyant microspheres was separated from the settled microspheres by filtration. Microspheres of both types were collected, dried, and weighed. The buoyancy of microspheres was determined using the following formula; [16].

$$Buoyancy\ (\%) = \frac{Wf}{Wf+Ws} X\ 100 \text{ where, } Wf = \text{Weight of floating microspheres}$$

Ws = Weight of settled microspheres

In vitro drug release studies

An *in vitro* drug release studies were carried out in USP type II (Paddle type) dissolution apparatus using simulated gastric fluid (pH-1.2) as dissolution medium under sink conditions. Accurately weighed samples of floating microspheres were introduced into 900 ml of dissolution medium maintained at 37±0.5 °C with paddle rotating at 100rpm. The adequate samples were withdrawn at the interval of 1 hour and the same volume of fresh medium was refilled to maintain sink condition. After suitable dilutions, the samples were analyzed spectrophotometrically at a specific wavelength. To understand the mechanism and kinetics of *in vitro* drug release studies of all formulations were subjected to the goodness of fit test by linear regression analysis, according to zero-order and first-order kinetics equations, Korsemeyer Peppa's and Higuchi model [17].

Drug content determination

Drug content was determined using UV-Spectrophotometer. Drug-loaded microspheres were crushed and 100 mg was suspended in 100 ml 0.1N HCl solution. This suspended solution was kept for 24h. It was stirred for 5 min and filtered. Ciprofloxacin content in the filtrate was determined spectrophotometrically at 275 nm using a regression derived from the standard curve [9].

Swelling index determination

The swelling index behavior of the floating microspheres was measured by studying its weight gain. To determine the swelling index the microspheres were kept in the dissolution apparatus using the dissolution medium 0.1N HCl at 37±0.5 °C. After 0.5, 1, 2, 3, 4, 5, and 6 h, each microsphere from the dissolution apparatus was withdrawn, blotted with tissue paper to remove the excess water, and weighed on the analytical balance. The experiment was performed in triplicate at each time point. The swelling index was determined by the following formula; [18]

$$\text{Swelling Index} = \frac{\text{Wet weight of the microspheres} - \text{Dry weight of the microspheres}}{\text{Dry weight of microspheres}}$$

RESULTS AND DISCUSSION

The cumulative drug release depends on the type and amount of polymer used. The polymers used in combination affect the release rate [9]. In this research, floating microspheres of ciprofloxacin were prepared by carbopol 940, ethylcellulose, and hydroxypropylmethyl cellulose (HPMC K4M) by the solvent evaporation method. Polymers used individually showed better results as compared in combination with other polymers. So individual polymers were used for the preparation of ciprofloxacin microspheres. F1 to F3 formulations were prepared using carbopol 940, F4 to F6 formulations were prepared using ethylcellulose and F7 to F9 formulations were formulated using hydroxypropylmethyl cellulose with an increasing concentration of polymers. In this research, the drug concentration was kept constant. Floating microspheres prepared by solvent evaporation were discrete, free-flowing, and spherical in shape.

λ max of ciprofloxacin was found at 275 nm. The absorbance of the dilutions was measured at 275 nm using 0.1N HCl as blank. A graph was plotted by taking absorbance on Y-axis and concentration on X-axis, which gave a straight line (fig. 2). Values for absorbance are shown in table 2.

Table 2: Concentration versus Absorbance of ciprofloxacin

S. No.	Concentration (µg/ml)	*Absorbance±SD
1	0	0
2	1	0.068±0.002
3	2	0.125±0.001
4	3	0.237±0.001
5	4	0.354±0.002
6	5	0.433±0.001
7	6	0.522±0.001

*Each value is the average of three experiments±Standard Deviation (SD)
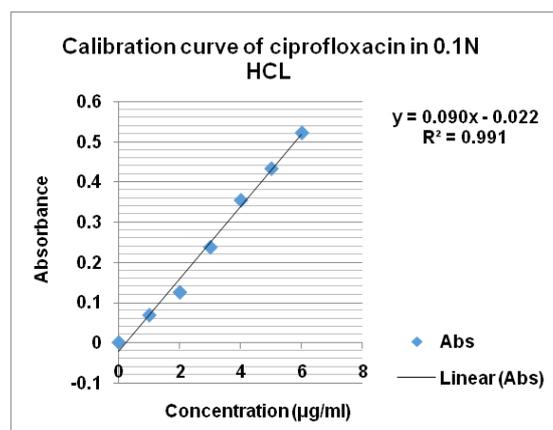
Fig. 2: Calibration curve of ciprofloxacin

Characteristic peaks were observed for the drug as shown in table 3. Major functional groups showed characteristic peaks (fig. 3).

Table 3: Characteristic peak value of the ciprofloxacin

S. No.	Group	Theoretical peak value (cm⁻¹)	Observed peak value (cm⁻¹)
1.	C-F stretching	1400-1000	1095.60
2.	O-H bending	1300-1250	1288.49
3.	O-H stretching	3300-2500	2638.71
4.	C-O stretching	1450-1400	1435.09
5.	C-H stretching	3300-2800	3286.81
6.	N-H stretching	3700-2500	2700.43
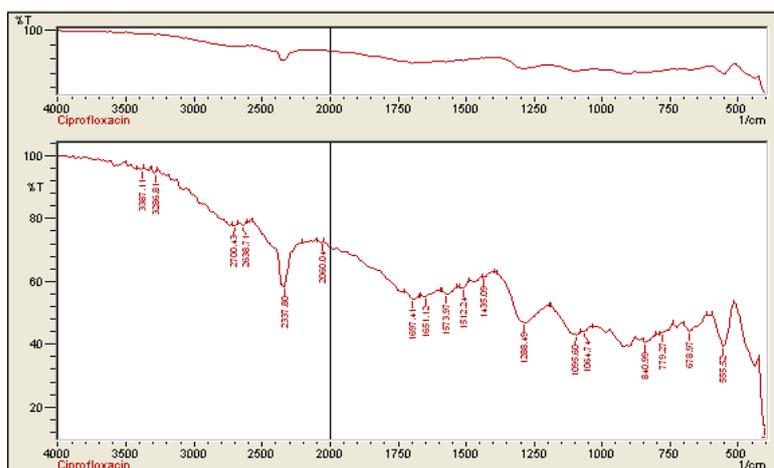
Fig. 3: FTIR spectrum of ciprofloxacin

The FTIR study was conducted using the FTIR instrument. IR spectrum of the pure drug was found to be similar to that of the standard IR spectrum of ciprofloxacin. The shift in peak and change in the shape of the peak was not observed. Fourier Transform Infrared spectra of the drug-polymer mixture indicated that there was no interaction between the drug and polymer as shown in fig. 4, 5, and 6 respectively. Thus carbopol, ethylcellulose, and HPMC K4M were chosen for the preparation of floating microspheres.

Fig. 4: FTIR spectrum of the mixture (Ciprofloxacin and carbopol 940)

Fig. 5: FTIR spectrum of the mixture (Ciprofloxacin and ethylcellulose)

Fig. 6: FTIR spectrum of the mixture (Ciprofloxacin and HPMC K4M)

All formulations of floating microspheres F1 to F9 were evaluated for various micromeritic parameters like bulk density, tapped density, Hausner's ratio, angle of repose, and % compressibility index as shown in table 4. The comparison between the bulk density and tapped density gives an idea about the interaction in the powder such comparison determines the ability of the powder to flow. The Hausner's ratio was found to be in the range of 1.14-1.18 which showed good flow property. The angle of repose and % compressibility index was also found to be in the range which showed the good flowing property. According to the literature, the values were in the range which indicated good flow property. This suggests that the microspheres can be easily handled during processing. The value of Hausner's ratio of all the formulations was below 1.25 which indicated good and better flow properties [19].

Table 4: Micromeritic properties of floating microspheres

Formulation code	*Bulk density (gm/cm³)	*Tapped density (gm/cm³)	Hausner's ratio	*Angle of repose (°)	*Carr's index
F1	0.014±0.01	0.016±0.001	1.14	31.92±2.33	14.28±0.02
F2	0.016±0.01	0.019±0.002	1.18	32.35±1.47	12.00±0.03
F3	0.022±0.01	0.025±0.001	1.13	35.64±0.91	18.75±0.05
F4	0.017±0.01	0.020±0.001	1.17	29.68±1.46	17.64±0.01
F5	0.016±0.01	0.019±0.001	1.18	30.86±2.24	18.75±0.08
F6	0.020±0.01	0.023±0.002	1.15	33.69±2.56	15.00±0.07
F7	0.015±0.01	0.017±0.001	1.13	31.89±1.26	13.33±0.05
F8	0.018±0.01	0.021±0.002	1.16	34.72±1.49	16.66±0.01
F9	0.018±0.01	0.021±0.001	1.16	30.56±2.76	16.66±0.02

*Each value is the average of three experiments±Standard Deviation (SD)

Floating microspheres of ciprofloxacin which were prepared by the solvent evaporation method were weighed after drying and the percentage yield of microspheres containing carbopol 940 is less as compared to ethylcellulose and HPMC K4M. The percentage yield of microspheres containing ethylcellulose (86.00±2.84 to 95.01±1.09) was found to be less as compared to HPMC K4M (87.52±2.56 to 96.58±2.23). The floating microspheres containing carbopol, ethylcellulose, and HPMC K4M showed a percentage yield from 67.50±1.20 to 96.58±2.23. Experimentally it can be concluded that % yield value increased with increasing polymer concentration (table 5). According to a previous study, as the polymer ratio was increased the product/percentage yield also increased. The low percentage yield in some formulations may be due to the loss of microspheres during the washing process [20].

Table 5: Percentage yield of floating microspheres

Formulation code	*Percentage yield (%)
F1	67.50±1.20
F2	83.66±1.72
F3	93.75±1.26
F4	86.00±2.84
F5	90.67±0.89
F6	95.01±1.09
F7	87.52±2.56
F8	93.84±1.03
F9	96.58±2.23

*Each value is the average of three experiments±SD

The particle size of the floating microspheres of ciprofloxacin was measured using an optical microscope and was found to be increased with an increase in the polymer concentration as shown in table 6. The particle size of all formulations was ranged from 258.1±2.21 μm to 278.2±2.86 μm. The particle size of the microspheres increased due to the viscosity of the polymer solution. As the viscosity of the polymer increases with increasing polymer concentration which results in enhanced interfacial tension decreased stirring efficiency and particle size. According to a previous study, as the concentration of the polymer was increased, the particle size also increased. This is due to the viscosity of the polymers used in the formulation. The higher the concentration of the polymer solution, the lower was the stirring rate. Due to this nature, the polymer rapidly precipitates which leads to hardening and avoids a further reduction in the particle size during solvent evaporation [21].

Table 6: Particle size of microspheres

Formulation code	*Particle size (μm)
F1	258.1±2.21
F2	260.3±3.39
F3	272±4.17
F4	265.3±3.17
F5	269.7±4.26
F6	274.4±3.07
F7	266.7±2.59
F8	273±3.18
F9	278.2±2.86

*Each value is the average of three experiments±SD

The percent drug entrapment efficiency of ciprofloxacin microspheres of all batches was found to be in the range of 63.17±0.43% to 89.90±1.32%. The entrapment efficiency of HPMC was found to be more when the concentration of the polymer was increased in the drug: polymer ratio as compared to carbopol and Ethylcellulose as shown in table 7. As the polymer concentration is increased more particles are coated and which leads to higher entrapment efficiency. According to the literature, entrapment efficiency was increased with an increase in the polymer concentration. From the results, it can be concluded that there is proper distribution of the drug in the microspheres and the deviation is within the acceptable limit. As the polymer concentration was increased, the entrapment efficiency also increased [22].

Table 7: % Drug entrapment efficiency of floating microspheres

Formulation code	*Entrapment efficiency (%)
F1	72.43±1.19
F2	74.38±2.36
F3	78.90±1.57
F4	63.17±0.43
F5	76.32±1.13
F6	84.11±2.78
F7	86.37±1.23
F8	88.21±2.66
F9	89.90±1.32

*Each value is the average of three experiments±SD

The floating capacity of the ciprofloxacin microspheres of all batches was ranged from 81.89±1.22% to 95.78±3.68%. As the concentration of the polymer was increased the floating capacity of

the microspheres also increased as shown in table 8. The increase in floating percentage was attributed to air and gel-forming polymer. The microspheres prepared by HPMC K4M remained floating for more than 15h than the microspheres prepared by carbopol and ethylcellulose. According to a previous study, it was reported that as the amount of the polymer was increased the floating capacity of the microspheres also increased. The increase in the floating capacity may be due to air and gel-forming polymer, which causes swelling because of the increased amount of polymers [23].

Table 8: Floating capacity of microspheres

Formulation code	*Floating capacity (%)
F1	81.89±1.22
F2	83.67±2.33
F3	84.71±2.98
F4	85.26±2.33
F5	90.02±2.88
F6	91.63±3.01
F7	91.22±1.30
F8	95.64±2.33
F9	95.78±3.68

*Each value is the average of three experiments±SD

The release study of ciprofloxacin floating microspheres was studied in simulated gastric fluid (pH 1.2) for 10 h in USP type II dissolution apparatus and % drug release is shown in table 9. F1 to F3 formulations were prepared using carbopol 940 polymer. As the carbopol 940 concentration was increased the drug release decreased. Drug release ranged from 56.47% (High concentration of carbopol) to 78.22% (Low concentration of carbopol). Other formulations F4 to F6 prepared by ethylcellulose gave good release as compared to carbopol. But the formulations prepared by HPMC K4M (F7 to F9) gave satisfactory release as compared to ethylcellulose and carbopol. Since it showed prolonged drug release at the end of 10 h.

Drug release of the floating microspheres was controlled by the polymer. As the polymer concentration (carbopol, ethylcellulose, and HPMC) was increased the drug release was decreased significantly, as shown in fig. 7. This may be due to the increased density of the polymer at higher concentrations which results in increased diffusional path length. HPMC helps the dosage form to control the release rate at the desired time. The drug release of HPMC was found to be more as compared to carbopol and ethylcellulose and decreased with an increase in the polymer ratio used. F7 formulation showed slow release of the drug, so it was considered as an optimized batch prepared by HPMC K4M. According to the literature, the cumulative release was decreased significantly with an increase in the polymer concentration. The increased density of the polymer matrix at higher concentrations results in an increased diffusional path length. This may decrease the overall drug release from the polymer matrix. Therefore, smaller microspheres were formed at lower concentration and have a larger surface area exposed to dissolution medium, which gives rise to faster release of drug [24].

Table 9: % Cumulative drug release of floating microspheres

Time in h	*Percentage (%) cumulative drug release								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
1	5.00±0.88	4.60±0.97	4.60±1.97	4.59±0.97	4.60±0.78	4.48±0.97	4.60±0.97	5.00±0.97	4.59±0.97
2	10.41±0.68	9.41±0.90	9.41±1.95	10.21±1.72	9.41±1.90	9.61±0.86	10.81±0.59	10.21±0.72	10.01±0.17
3	16.42±0.42	14.62±0.74	14.62±1.74	16.62±0.30	14.82±0.75	15.02±0.66	18.21±0.95	16.42±0.35	16.24±0.35
4	23.02±1.88	20.23±0.50	20.23±1.03	23.62±0.74	21.03±1.32	21.23±0.28	26.42±0.12	23.22±0.38	23.42±0.79
5	30.23±0.28	26.44±1.12	25.64±1.33	31.03±0.04	27.63±0.85	28.23±0.72	35.62±0.84	30.83±0.14	30.63±0.19
6	38.03±0.44	33.04±0.65	31.25±1.25	39.03±1.33	35.04±1.21	35.44±1.12	45.61±0.86	39.23±0.28	38.23±0.50
7	47.03±1.54	40.45±0.11	37.25±0.75	47.36±1.14	43.24±0.39	43.24±0.90	56.21±0.50	48.43±0.23	46.43±0.68
8	56.83±0.37	48.45±1.23	43.46±1.34	56.83±1.33	51.84±1.47	51.26±0.61	67.21±0.64	58.62±0.97	55.03±0.76
9	67.23±0.05	56.85±0.36	49.86±0.91	66.23±1.28	61.24±0.39	59.44±0.78	78.60±0.53	69.42±0.57	64.23±0.72
10	78.22±0.61	68.85±1.36	56.47±1.45	76.23±0.59	71.24±1.16	67.84±0.92	90.79±0.82	81.01±0.99	73.83±0.59

*Each value is the average of three experiments±SD
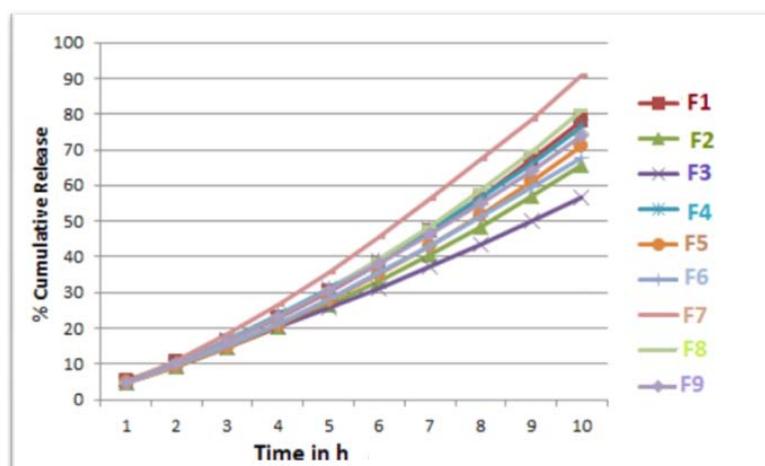
Fig. 7: Cumulative release of floating microspheres (F1 to F8)

The mechanism of drug release from the microspheres can also be studied using kinetic models. The optimized formulation did not show any burst-out effect. The dissolution data were subjected to regression analysis and were fitted into five kinetic models i.e. zero-order, first-order, Hixson Crowell, Korsmeyer-Peppa's, and Higuchi's model. The formulations followed Korsmeyer-Peppa's model, shown

in fig.8. The drug release is evaluated using this model. The n-value for the batch was found to be more than 0.89 as shown in table 10, which confirmed that the drug release from the system follows Super case II transport. According to the literature, n (release component) was higher than 0.89 which implies that the drug release from the system follows super case II transport [25].

Table 10: Release rate kinetics of F7 optimized formulation

Formulation code	Zero order (r^2)	First order (r^2)	Hixson crowell (r^2)	Korsmeyer-peppa's (r^2)	Higuchi (r^2)
F7	0.9919	0.929	0.9807	0.9996	0.9492
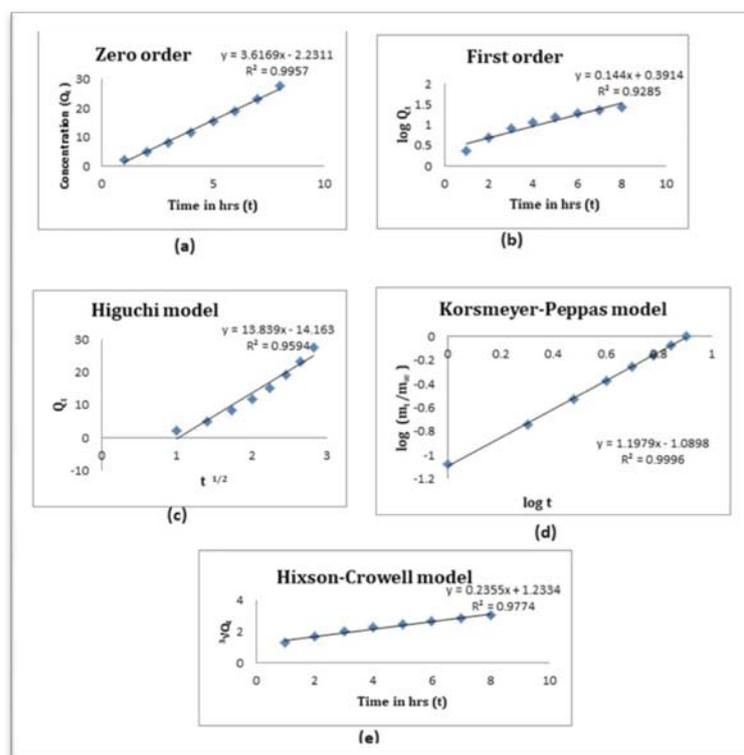
Fig. 8: Release kinetics plot of F7 formulation

The drug content of all formulations was found to be increased with an increase in the concentration of polymer as shown in table 11. As the concentration of the polymer is increased more drug particles will be bound by the polymers. The drug content also depends on the % yield of floating microspheres. HPMC K4M based formulations show higher drug content (73.07±2.40 to 83.59±4.86%) as compared to other polymer-based formulations. According to the previous study, as the polymer concentration in the internal phase was increased the drug content also increased. This may be due to an increase in viscosity of the internal phase which reduces the migration of the drug in an aqueous phase, thus entrapping a greater amount of drugs [26].

Table 11: Drug content of floating microspheres

Formulation code	*Drug content (%)
F1	65.07±3.72
F2	67.11±4.23
F3	69.72±4.38
F4	70.07±2.40
F5	71.42±3.36
F6	72.07±1.23
F7	73.43±2.40
F8	80.17±3.36
F9	83.59±4.86

Swelling behaviour also determines the release rate of the drug from the dosage form. Greater the swelling capacity greater the release rate of the drug from the dosage form. Carbopol containing microspheres and ethylcellulose containing microspheres did not swell much as compared to HPMC containing microspheres. The swelling index of HPMC K4M containing formulations were found to be more as compared to other formulations as shown in table 12. Ethylcellulose formulations did not swell much as compared to carbopol and HPMC. According to a previous study, the greater the swelling greater was the release from the microspheres. Formulations prepared with ethylcellulose showed no significant increase in swelling behaviour. Hydroxypropylmethyl cellulose showed greater swelling as compared to ethylcellulose. Percent swelling was dependent on water uptake characteristics of the polymer as well as polymeric chain relaxation capability [9].

Table 12: % Swelling index of floating microspheres

Formulation code	*Swelling index (%)
F1	18.27±1.22
F2	28.72±2.65
F3	33.9±1.36
F4	15.69±1.27
F5	20.76±2.36
F6	26.31±1.24
F7	21.36±1.69
F8	34.56±1.49
F9	45.76±2.43

*Each value is the average of three experiments±SD

CONCLUSION

The floating microspheres of ciprofloxacin were successfully prepared using the polymers like carbopol 940, ethylcellulose, and

HPMC K4M by the solvent evaporation method. Floating microspheres of ciprofloxacin can achieve a prolonged therapeutic effect by a controlled release mechanism of the drug for an extended of period time in the stomach. The floating microsphere increases the gastric residence time as well as bioavailability and decreases the dosing frequency of the drug. F7 formulation was found to be the optimized formulation due to the controlled release of the drug at the end of 10 h. The release was found to be 90.79±0.89%. The floating microspheres not only increase the bioavailability of the drug it also improves patient compliance.

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AUTHORS CONTRIBUTIONS

All authors in the present research study have contributed their equal parts. Kauslya Arumugam has collected the data, designed the study and performed the experimental work. Payal D. Borawake has interpreted the data. The research was guided and supervised by Jitendra V. Shinde. All authors contributed to the manuscript writing.

CONFLICT OF INTERESTS

None

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