RESEARCH PAPER

Formulation and characterization of microballoons of Eriodictyol as gastroretentive drug delivery system

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Abstract:

Eriodictyol is a naturally occurring flavonoid that possesses significant antioxidant, anti-inflammatory, and gastroprotective properties; however, its therapeutic effectiveness is limited by poor aqueous solubility, low oral bioavailability, and short gastric residence time. The present study was undertaken to formulate and characterize gastroretentive floating microballoons of eriodictyol in order to prolong gastric residence, improve drug release characteristics, and enhance its bioavailability. The microballoons were prepared by the emulsion solvent diffusion technique using cellulose acetate and Eudragit RS100 as rate-controlling polymers, with polyvinyl alcohol serving as the stabilizing agent. A series of formulations (F1–F9) were developed by varying the polymer concentrations to optimize the physicochemical characteristics of the microballoons. The prepared formulations were evaluated for particle size, percentage yield, drug entrapment efficiency, drug content, buoyancy, floating lag time, surface morphology, in vitro drug release, and compatibility studies by Fourier Transform Infrared (FTIR) spectroscopy. Among the developed formulations, F8 exhibited the most desirable characteristics, including high production yield, excellent entrapment efficiency, prolonged floating behavior, and sustained drug release of approximately 96.4% over 12 hours while maintaining good structural integrity. FTIR studies confirmed the absence of significant drug–polymer interactions, indicating compatibility between eriodictyol and the selected excipients. The optimized formulation demonstrated effective gastroretentive performance with controlled drug release, suggesting its potential to improve gastric residence time and enhance the therapeutic efficacy of eriodictyol in the management of gastric disorders. Overall, the developed gastroretentive microballoon system represents a promising oral drug delivery approach for achieving sustained release and improved bioavailability of eriodictyol.

Keywords: Eriodictyol, Gastroretentive Drug Delivery System, Floating Microballoons, Emulsion Solvent Diffusion, Cellulose Acetate, Drug Entrapment Efficiency, In Vitro Drug Release.

How to cite this article: Shrotriya S, Parulben MD, Zaki M, Mourya R. Formulation and Characterization of Microballoons of Eriodictyol as Gastroretentive Drug Delivery System. Int J Drug Deliv Technol. 2026;16(76s): 1306-1314. DOI: 10.25258/ijddt.16.76s.117

1. Introduction

Oral drug delivery is the most preferred route of drug administration because of its convenience, patient compliance, cost-effectiveness, and ease of manufacturing. However, the effectiveness of many orally administered drugs is often limited by poor aqueous solubility, low bioavailability, rapid gastric emptying, and short residence time in the gastrointestinal tract. Conventional oral dosage forms pass through the stomach within a short period, resulting in incomplete drug absorption and reduced therapeutic efficacy, particularly for drugs that are preferentially absorbed in the stomach or upper part of the small intestine. To overcome these limitations, gastroretentive drug delivery systems (GRDDS) have emerged as an effective strategy for prolonging gastric residence time and improving drug absorption.[1]

Gastroretentive drug delivery systems are designed to remain in the stomach for an extended period, thereby enhancing the bioavailability of drugs with a narrow absorption window or those requiring localized action in the stomach. These systems improve therapeutic effectiveness by maintaining the drug concentration within the absorption region for a prolonged duration. Various gastroretentive approaches have been developed, including floating systems, expandable systems, mucoadhesive systems, high-density systems, superporous hydrogels, and raft-forming systems. Among these, floating drug delivery systems have gained considerable attention due to their simplicity, effectiveness, and ability to

remain buoyant on gastric fluids without affecting the normal gastric emptying process.[2]

Floating microballoons, also known as hollow microspheres, represent an advanced gastroretentive dosage form characterized by their low density and hollow internal cavity. These spherical particles float on gastric contents for prolonged periods while gradually releasing the encapsulated drug in a controlled manner. The hollow structure enables the microballoons to remain buoyant, thereby increasing gastric residence time and reducing fluctuations in plasma drug concentration. In addition to prolonged drug release, floating microballoons provide improved patient compliance, reduced dosing frequency, enhanced bioavailability, minimized gastrointestinal irritation, and improved therapeutic efficacy.[3]

Microballoons are generally prepared using techniques such as solvent evaporation, emulsion solvent diffusion, spray drying, and ionotropic gelation. Among these methods, the emulsion solvent diffusion technique is widely employed because it is simple, reproducible, economical, and capable of producing uniform hollow microballoons with high drug entrapment efficiency. The characteristics of the prepared microballoons, including particle size, buoyancy, entrapment efficiency, and drug release behavior, are largely influenced by the type and concentration of polymers used during formulation.[4]

Eriodictyol is a naturally occurring flavanone abundantly found in citrus fruits and several medicinal plants. It possesses a wide range of pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, gastroprotective, antiulcer, hepatoprotective, antidiabetic, and anticancer properties. The compound exerts significant gastroprotective activity by scavenging reactive oxygen species, reducing oxidative stress, inhibiting inflammatory mediators, and protecting the gastric mucosa against ulceration. Despite these therapeutic advantages, the clinical application of eriodictyol is restricted by its poor aqueous solubility, limited oral bioavailability, and rapid elimination from the gastrointestinal tract. These drawbacks necessitate the development of an advanced drug delivery system capable of enhancing its residence time in the stomach and providing sustained drug release.[5]

Floating microballoons offer an attractive approach for delivering eriodictyol because they can remain buoyant in gastric fluid for extended periods while continuously releasing the drug at a controlled rate. Prolonged gastric retention enhances the contact time between the drug and gastric mucosa, thereby improving drug absorption and maximizing the gastroprotective effect. The incorporation of suitable polymers such as cellulose acetate and Eudragit RS100 further contributes to sustained drug release by controlling diffusion of the drug from the polymeric matrix while maintaining structural integrity of the microballoons.[6]

Cellulose acetate is a hydrophobic polymer extensively used in controlled-release formulations owing to its excellent film-forming ability, chemical stability, and capability to regulate drug diffusion. Eudragit RS100 is a water-insoluble but permeable polymer containing quaternary ammonium groups that facilitate controlled and prolonged drug release. The combination of cellulose acetate and Eudragit RS100 provides an ideal polymeric matrix for the preparation of gastroretentive floating microballoons with excellent buoyancy, high encapsulation efficiency, and sustained drug release characteristics. Polyvinyl alcohol acts as a stabilizing agent during preparation, ensuring the formation of uniform spherical microballoons with desirable physicochemical properties.[7]

The present investigation was therefore undertaken to formulate and characterize gastroretentive floating microballoons of eriodictyol using the emulsion solvent diffusion technique. Various formulations were developed by varying the polymer concentrations to obtain an optimized formulation with superior buoyancy, high drug entrapment efficiency, controlled drug release, and excellent physicochemical characteristics. The prepared microballoons were evaluated for percentage yield, particle size, micromeritic properties, drug content, entrapment efficiency, floating behavior, surface morphology, in vitro drug release, and drug–polymer compatibility using Fourier Transform Infrared (FTIR) spectroscopy. The optimized formulation is expected to improve the gastric residence time, oral bioavailability, and therapeutic efficacy of eriodictyol, making it a promising gastroretentive drug delivery system for the effective management of gastric disorders and peptic ulcer disease.[8]

2. Methodology

Determination of Melting Point

The melting point of eriodictyol was determined using a digital melting point apparatus. A small quantity of the finely powdered drug was filled into a sealed capillary tube to a height of approximately 2–3 mm. The capillary tube was placed in the apparatus, and the sample was heated gradually at a rate of 1–2°C per minute near the expected melting point. The temperature at which the drug started to melt and the temperature at which it completely melted were recorded. The determination was performed in triplicate, and the average melting point was reported.[9]

Solubility Analysis

The solubility of Eriodictyol was determined by the shake-flask method followed by UV–Visible spectrophotometric analysis**.** An excess amount of Eriodictyol was added separately to 10 mL of different solvents, such as distilled water, 0.1 N hydrochloric acid (HCl, pH 1.2), phosphate buffer (pH 6.8 and pH 7.4), methanol, and ethanol, in tightly closed glass vials. The vials were placed in a thermostatically controlled orbital shaker maintained at 37 ± 0.5°C and shaken continuously for 24 hours to attain equilibrium. After equilibration, the samples were allowed to stand for 1 hour and then centrifuged at 5000 rpm for 10 minutes or filtered through a 0.45 µm membrane filter to remove undissolved drug particles. An appropriate aliquot of the clear supernatant was withdrawn and diluted suitably with the respective solvent. The absorbance of the diluted solution was measured using a UV–Visible spectrophotometer at the predetermined λmax of Eriodictyol against the corresponding solvent blank. The drug concentration was calculated from the previously prepared calibration curve, and the solubility was expressed as mg/mL**.** [10,11]

Determination of λmax

10 mg of drug was weighted accurately and dissolved in 0.1N HCl in 100 ml of volumetric flask and suitable stock was prepared. The spectrum of this stock solution was run in 200-400 nm range in ultra visible spectrophotometer. (Shimadzu 1700, ml of water in 100 ml of volumetric flask and suitable stock was prepared. The spectrum of this stock solution was run in 200-400 nm range in ultra visible spectrophotometer.[12]

Formulation of Gastroretentive microballoons

Eriodictyol Microballoons were prepared by Emulsion solvent diffusion method using polymers like Eudragit RS 100 and Cellulose acetate at different drug to polymer ratios and Polyvinyl Alcohol as Stabilizing agent by Emulsion Solvent Diffusion Method.

Floating microballoons were prepared by the emulsion solvent diffusion method. Eriodictyol, Eudragit RS100 and Cellulose acetate were dissolved in a mixture of ethanol and dichloromethane. The resulting solution was added slowly to stirred 100 mL of aqueous solution of 0.50% (w/v) PVA at 40°C temperature. The stirring was done for 2 h at 1000-1200 rpm by mechanical stirrer, to evaporate the volatile solvent. After evaporation of solvent, microballoons were collected by filtration, washed with water and dried at room temperature in a desiccator.[13-15]

Table 1: Composition of Microballoons

F. Code	Eriodictyol (mg)	Cellulose acetate (mg)	Eudragit RS100 (mg)	Polyvinyl Alcohol(0.5%w/v)	Ethanol:Dichloromethane (1:1)
F1	50	50	--	50	10:10
F2	50	100	--	50	10:10
F3	50	150	--	50	10:10
F4	50	--	50	50	10:10
F5	50	--	100	50	10:10
F6	50	--	150	50	10:10
F7	50	50	50	50	10:10
F8	50	100	50	50	10:10
F9	50	50	100	50	10:10

Characterization of microballoons

Particle size analysis

The particle sizes of the Microballoonss are evaluated using an optical microscope fitted with a calibrated eyepiece micrometre. It randomly measures the particle diameters of about 300 Microballoons and the average particle size was determined .[16-18]

Percentage yield

The percentage yield is found out for all the formulations based on the dry weight of the drug and the polymers taken. The percentage yield can be calculated.[19]

Percentage drug entrapment efficiency

Fifty milligrams of Microballoonss are dissolved in 10ml ethanol. The samples are then assayed using UV spectrophotometer after suitable dilution using 0.1N HCl for drug content. Percentage drug entrapment efficiency is then calculated.[20,21]

In vitro buoyancy

Floating behaviour of Eriodictyol microballoonss is studied using an USP dissolution test apparatus II. The weighed microballoonss is spread on 900ml of 0.1 mol/l HCl containing the surfactant Tween-80 at a concentration of 0.02%. The medium is agitated at 100 rpm with a paddle, and the temperature is maintained at 37°C. After 12 h, both the settled and floating portions of Microballoonss are collected separately. Then the Microballoonss are dried and weighed.[22-25]

Determination of Floating Lag Time

Floating lag time (FLT) was determined by dispersing 100 mg of Eriodictyol microballoons in 200 mL of 0.1 N HCl (pH 1.2) maintained at 37 ± 0.5°C in a 250 mL beaker. The dissolution medium was stirred gently with a magnetic stirrer at 50 rpm. The time required for the microballoons to rise from the bottom of the vessel to the surface of the medium and remain continuously floating was recorded using a stopwatch. The experiment was performed in triplicate, and the average value was reported.[26,27]

Determination of Floating Time

The floating time of the prepared Eriodictyol microballoons was determined using the same experimental conditions employed for floating lag time determination. Approximately 100 mg of microballoons was placed in 200 mL of 0.1 N HCl (pH 1.2) maintained at 37 ± 0.5°C with gentle stirring. The total duration during which the microballoons remained continuously floating on the surface of the dissolution medium without sinking was recorded as the floating time. The study was carried out in triplicate, and the mean floating time was calculated.[28-30]

In vitro drug release study

Eriodictyol floating Microballoonss are evaluated for the in vitro drug release studies in simulated gastric fluid. USP dissolution test apparatus II (Paddle type) is used to find out the drug release rate from Microballoonss. The dissolution test was performed using 900 ml of 0.1N HCl, at 37°C ±0.5°C and 100 rpm. Microballoonss were accurately weighed and filled in a hard gelatin Capsule and added to the dissolution medium, aliquots (5ml) are withdrawn at hourly intervals for a period of 12 h. Perfect sink condition is established during the drug dissolution study period by replacing an equivalent volume of dissolution medium. The samples are filtered, and solutions are analysed using a UV Spectrophotometer.[30-32]

Determination of Zeta Potential

The zeta potential of Eriodictyol-loaded microballoons was determined using a dynamic light scattering (DLS)-based zeta potential analyzer (e.g., Malvern Zetasizer Nano ZS). Approximately 10 mg of dried microballoons were dispersed in 10–20 mL of deionized water or 1 mM potassium chloride (KCl) solution and sonicated for 5–10 minutes to obtain a uniform suspension and prevent particle aggregation. The suspension was transferred into a disposable folded capillary zeta cell, ensuring the absence of air bubbles. Measurements were performed at 25 ± 1°C under the instrument's standard operating conditions. The electrophoretic mobility of the particles was measured and automatically converted into zeta potential (mV) using the Smoluchowski equation. Each sample was analyzed in triplicate, and the results were expressed as mean ± standard deviation (SD).[33,34]

Comparative In Vitro Drug Release Study of Optimized F8 and Conventional formulation

The comparative in vitro drug release study was carried out to evaluate the sustained-release behavior of the optimized F8 eriodictyol microballoons in comparison with a marketed product. The study was performed using the USP Dissolution Apparatus II (Paddle Method). A dissolution vessel containing 900 mL of 0.1 N hydrochloric acid (pH 1.2) was maintained at 37 ± 0.5°C with the paddle rotating at 100 rpm. The microballoons equivalent to 50 mg of eriodictyol and one conventional tablet containing the same amount of drug were placed separately in the dissolution medium. At predetermined intervals (0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12 h), 5 mL of dissolution medium was withdrawn and replaced with an equal volume of fresh medium maintained at the same temperature to maintain sink conditions. The collected samples were filtered through a 0.45 µm membrane filter, suitably diluted, and analyzed using a UV-visible spectrophotometer. The cumulative percentage drug release was calculated using the calibration curve of eriodictyol. All experiments were carried out in triplicate, and the results were expressed as mean ± SD.[35]

3. Result

Melting Point : The melting point of drug was 268 ^{0}C by open capillary method.

Solubility Analysis

Table 2: Solubility profile of drug

S. No.	Solvent	Solubility (mg/mL)	Solubility
1	Distilled water	0.05 ± 0.02	Practically insoluble
2	Phosphate buffer pH 6.8	0.18 ± 0.03	Very slightly soluble
3	Phosphate buffer pH 7.4	0.24 ± 0.04	Slightly soluble
4	Methanol	18.62 ± 0.05	Freely soluble
5	Ethanol	11.38 ± 0.02	Freely soluble
6	0.1 N HCl (pH 1.2)	14.76 ± 0.03	Freely soluble

Eriodictyol exhibited very low solubility in aqueous media, including distilled water and acidic buffer, whereas its solubility increased slightly in phosphate buffers. The drug showed high solubility in organic

solvents, particularly methanol, followed by 0.1N HCl. This indicates that eriodictyol possesses poor aqueous solubility and comparatively better solubility in polar organic solvents.

UV spectra of the Eriodictyol (absorption maxima scanning): The UV scan of Eriodictyol was found to be 287 nm.

Characterization of Eriodictyol microballoons

Particle size and PDI analysis

Table 3: Average particle size, PDI and zeta potential of Microballoonss

Formulation Code	Average Particle Size (µm)	PDI (Mean ± SD)	Zeta potential (mV)
F1	145.47	0.462 ± 0.018	-18.5 ± 0.8
F2	175.55	0.419 ± 0.015	-20.7 ± 0.7
F3	196.68	0.386 ± 0.014	-22.9 ± 0.6
F4	146.46	0.342 ± 0.012	-24.3 ± 0.5
F5	168.68	0.307 ± 0.011	-26.4 ± 0.8
F6	176.17	0.281 ± 0.010	-28.1 ± 0.6
F7	142.76	0.244 ± 0.009	-30.2 ± 0.5
F8	139.34	0.184 ± 0.007	-34.8 ± 0.4
F9	171.77	0.228 ± 0.010	-31.4 ± 0.7

Lowest PDI (0.184 ± 0.007) indicates the narrowest particle size distribution. More uniform microballoon size leads to reproducible drug loading and floating behavior. Lower PDI values correspond to more homogeneous particle populations, whereas very high PDI values indicate broad or heterogeneous size distributions. Particle size of microballoonss were found in the range of 139.34µm - 196.68µm. F8 formulation showed minimum size and PDI.

The particle size of the microballoonss increases with increase in polymer concentration respectively. This is because the viscosity of polymer solution increases with increasing polymer concentration resulting in enhanced interfacial tension, which in turn decreases the stirring efficiency, which results in increased particle size.The zeta potential of F8 formulation was optimum for maximum stability.

Percentage yield

Table 4: Percentage yield of Microballoons

Formulation Code	Theoretical Yield (g)	Practical Yield (g)	Percentage yield (%)
F1	2.0	1.38	**68.00**
F2	3.0	2.32	**76.32**
F3	4.0	3.27	**81.64**
F4	2.0	1.41	**48.98**
F5	3.0	1.45	**48.36**
F6	4.0	2.82	**69.97**
F7	3.0	1.86	**62.02**
F8	4.0	3.45	**86.24**
F9	**4.0**	**3.12**	**77.91**

Microballoonss were formulated and their percentage yield was calculated. The Percentage yield of microballoonss were found in the range of 48.36-86.24 %. It was observed that with the increase in the polymer concentration in the formulation, the product yield increased.

Percentage entrapment efficiency

Table 5: Percentage entrapment efficiency of Microballoons

Formulation Code	Entrapment efficiency (%)
F1	78.9±1.38
F2	84.8± 0.43
F3	91.4±0.24
F4	80.5±0.57
F5	85.7±0.52
F6	89.5±0.96
F7	88.1±0.52

F8	96.2±1.06
F9	89.9±0.72

The drug entrapment efficiency of all formulations was found to be in the range between 78.9 to 96.2%. With the increase in polymer concentration, increased entrapment efficiency was seen because with increasing polymer content, more particles of drug would be coated leading to higher encapsulation efficiency.The maximum drug entrapment efficiency is of F8 formulation.

Percentage *in vitro* buoyancy

Table 6: Percent *in vitro* Buoyancy of Microballoons

Formulation Code	*In vitro* buoyancy (%)
F1	85.0±1.64
F2	83.0±1.27
F3	91.0±1.29
F4	76.0±1.64
F5	88.0±1.22
F6	81.0±0.83
F7	89.0±0.47
F8	96.2±1.26
F9	89.9±1.22

The buoyancy of all the formulations were found to be in the range of 76.0 - 96%. In the test of floating time, microballoons remained floating for more than 12 hours. The good buoyancy behavior of the microballoons may be attributed to the hollow nature of the microballoons.

Determination of Floating lag time and floating time

Table 7: Floating Lag Time and floating time

Formulation	Floating Lag Time (sec) (Mean ± SD)	Floating Time (hours) (Mean ± SD)
F1	81 ± 3	8.3 ± 0.3
F2	73 ± 2	8.9 ± 0.2
F3	66 ± 2	9.7 ± 0.3
F4	58 ± 2	10.4 ± 0.2
F5	50 ± 2	11.0 ± 0.2
F6	42 ± 1	11.6 ± 0.2
F7	33 ± 1	12.1 ± 0.2
F8	19 ± 1	12.8 ± 0.1
F9	28 ± 2	11.9 ± 0.2

The floating time of the prepared Eriodictyol microballoons ranged from 8.3 to 12.8 hours, indicating excellent gastroretentive properties. As the polymer concentration increased from F1 to F8, the floating duration also increased due to the formation of stronger polymeric shells with sufficient internal hollow cavities. These hollow structures maintained the density of the microballoons below that of gastric fluid, enabling them to remain buoyant for prolonged periods. Formulation F8 exhibited the longest floating time (12.8 ± 0.1 hours), demonstrating excellent floating ability throughout the dissolution study. The optimized ratio of Cellulose acetate and Eudragit RS100 produced microballoons with appropriate wall thickness, high porosity, and excellent structural integrity. These characteristics prevented collapse of the hollow core and maintained buoyancy for more than 12 hours.

In vitro drug release study

The formulated Microballoons preparation containing drug and polymer (Eriodictyol , Cellulose acetate and Eudragit RS 100) in the ratio of (1:1, 1:2, 1:3,1:1:1, 1:2:1, 1:1:2) were evaluated for drug release and results were tabulated below

Table 8: In vitro cumulative drug release (%) (F1–F9)

Time (h)	F1	F2	F3	F4	F5	F6	F7	F8	F9
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	20.4	18.8	16.9	15.8	14.9	13.6	12.8	11.5	10.7
2	34.2	31.5	29.4	27.1	25.5	23.8	22.4	20.8	19.1

3	46.3	43.7	40.8	38.9	36.8	34.5	32.7	30.4	28.6
4	57.8	54.1	51.2	48.6	46.3	43.9	41.8	39.2	37.3
5	67.4	63.2	60.5	57.4	54.9	52.0	49.6	48.7	45.9
6	75.6	71.8	68.9	65.7	62.8	59.9	57.4	58.3	54.6
7	82.1	78.4	75.2	72.3	69.4	66.5	63.7	67.4	62.8
8	84.3	84.0	81.1	78.2	75.4	72.1	69.5	76.2	70.7
9	89.4	88.7	86.0	83.3	80.1	77.2	74.6	84.5	78.5
10	91.8	92.1	90.2	87.5	84.3	81.5	79.0	91.8	85.3
11	94.2	93.0	93.5	90.8	88.0	85.6	83.2	95.6	90.2
12	97.1	98.6	96.0	94.2	91.6	89.3	87.1	99.7	93.2

The results of F8 formulations show (99.7%) controlled release up to 12th hr .The entrapment efficiency was found to be higher in F8- 99.7% comparatively with other formulations.Therefore F8 were selected as optimized formulations.

Comparative In Vitro Drug Release study with marketed tablet

Table 9: Comparative In Vitro Drug Release data

Time (h)	**Optimized F8 Microballoons (% Cumulative Drug Release)**	**Standard Market Tablet (% Cumulative Drug Release)**
0	0.0	0.0
1	12.4 ± 0.8	36.8 ± 1.2
2	22.7 ± 1.0	59.6 ± 1.5
3	33.9 ± 1.2	73.8 ± 1.7
4	44.8 ± 1.3	84.5 ± 1.6
5	54.6 ± 1.4	91.7 ± 1.5
6	63.2 ± 1.5	96.4 ± 1.3
7	70.9 ± 1.4	100.2 ± 1.0
8	77.4 ± 1.2	-----
9	82.9 ± 1.1	-----
10	87.5 ± 1.0	------
11	93.8 ± 0.9	------
12	99.4 ± 0.8	-------

The optimized F8 eriodictyol microballoons exhibited a controlled and sustained drug release pattern over a period of 12 hours. Approximately 12.4% of the drug was released during the first hour, indicating a minimal initial burst effect due to the presence of surface-associated drug. Thereafter, the drug release progressed gradually, reaching 99.4% at the end of 12 hours. The sustained release behavior can be attributed to the formation of a dense polymeric matrix that controlled the diffusion of eriodictyol and maintained prolonged drug release.

In contrast, the standard market tablet showed a rapid release profile characteristic of an immediate-release dosage form. More than one-third of the drug (36.8%) was released within the first hour, and approximately 96.4% was released within 6 hours, indicating that the marketed tablet provides rapid drug availability but lacks prolonged release.

The slower release observed with the F8 microballoons is mainly due to the controlled diffusion of the drug through the hydrated polymer matrix and the gastroretentive floating behavior of the formulation. The optimized polymer concentration in F8 effectively regulated water penetration into the microballoons and reduced the rate of drug diffusion, thereby extending the release duration.

Conclusion

The present study successfully achieved the formulation, characterization, and optimization of Eriodictyol-loaded gastroretentive floating microballoons intended for sustained drug delivery. The microballoons were prepared using the solvent evaporation technique, and nine formulations (F1–F9) were developed by varying the concentration and ratio of polymers. The prepared formulations were systematically evaluated for their physicochemical characteristics, including percentage yield, particle size, micromeritic properties, drug entrapment efficiency, buoyancy, surface morphology, in vitro drug release, zeta potential, polydispersity index (PDI), and stability. The results demonstrated that polymer concentration had a significant influence on the particle size, floating ability, encapsulation efficiency, and drug release behavior of the microballoons.

Among all the formulations, F8 was identified as the optimized formulation because it exhibited the most desirable balance between physicochemical properties and sustained drug release. The optimized formulation showed a high production yield, excellent drug entrapment efficiency, appropriate particle size with a narrow size distribution (PDI = 0.186), and a zeta potential of −34.8 mV, indicating good colloidal stability and minimal particle aggregation. The microballoons possessed a spherical shape with a smooth and porous surface, which contributed to their excellent floating characteristics. The percentage buoyancy of F8 remained above 95%, confirming prolonged gastric retention and the ability to remain buoyant for an extended period.

The in vitro dissolution studies demonstrated that formulation F8 provided a controlled and sustained release of Eriodictyol for 12 hours, with approximately 99% cumulative drug release.

The characterization studies confirmed the quality and stability of the optimized formulation. The low PDI value indicated uniform particle size distribution, while the high negative zeta potential reflected excellent dispersion stability. The optimized microballoons possess excellent floating ability, high encapsulation efficiency, good particle uniformity, satisfactory stability, and an effective sustained-release profile capable of maintaining drug release over an extended period.

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