INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Gastro Retentive Drug Delivery System: A Review

Patel Nrup*, Amar Raval

Sharda School of Pharmacy, Pethapur, Gandhinagar, Gujarat – 382610

ARTICLE INFO

Published: 8 Jan 2026
Keywords:
Buoyancy-Driven Drug Delivery, Floating Dosage Form, Gastroretentive System, Systematic Optimization, Gastric Residence Time, Critical Quality Attributes, Sustained Release.
DOI:
10.5281/zenodo.18186802

ABSTRACT

Buoyancy-Driven Drug Delivery Systems (BDDDS), commonly known as floating systems, represent a crucial strategy for optimizing the therapeutic performance of orally administered drugs that exhibit a narrow absorption window. This comprehensive review focuses specifically on the systematic methodology required to design and optimize these complex floating formulations to ensure reliable gastric retention. The review establishes the clinical necessity for prolonged gastric residence time (GRT) in managing chronic conditions, exemplified by the absorption challenges of Dihydropyridine Calcium Channel Blockers. The core of the article details the application of a quality-focused development paradigm for system optimization. This involves the rigorous identification, control, and functional correlation of Critical Material Attributes (CMAs) (e.g., polymer viscosity, concentration) and Critical Process Parameters (CPPs) (e.g., compression force) with the desired Critical Quality Attributes (CQAs). Key CQAs discussed include rapid Floating Lag Time (FLT), extended Total Floating Duration (TFT), optimal swelling kinetics, and stable sustained drug release[5]. By detailing this scientific approach, this review demonstrates how to reliably manufacture BDDDS to deliver predictable and superior performance.

INTRODUCTION

1.1. Gastroretentive Drug Delivery Systems (GRDDS)

Gastroretentive Drug Delivery Systems (GRDDS) are engineered to counter the limitations of rapid GI transit by physically prolonging the Gastric Residence Time (GRT) [1]. By retaining the dosage form in the stomach, GRDDS maximize drug release at the optimal site of absorption [2]. This strategy is vital for drugs that exhibit site-specific absorption in the upper GI tract, have limited stability at the higher pH of the lower intestinal milieu, or possess short biological half-lives, requiring sustained release at the site of absorption [3].

Objectives [4],

***Corresponding Author:** Patel Nrup
Address: *Sharda School of Pharmacy, Pethapur, Gandhinagar, Gujarat – 382610*
Email ✉ : patelnrup92@gmail.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

1. To review the physiological challenges in oral drug delivery, specifically relating to narrow absorption windows in the context of chronic hypertension management.
2. To outline the fundamental principles and classification of buoyancy-driven gastroretentive drug delivery systems, highlighting their mechanical and formulation differences.
3. To detail the application of a systematic development paradigm for optimizing the performance of floating systems by identifying and controlling critical variables.
4. To summarize the essential *in vitro* evaluation parameters used to characterize the critical performance attributes of buoyancy-driven systems.

1.2. Floating System

This review focuses specifically on the Buoyancy-Driven Drug Delivery System (BDDDS), or floating systems, which are a highly favored GRDDS approach due to their reliability in achieving GRT extension. Flotation is achieved by ensuring the dosage form maintains a net density less than that of gastric fluid (< 1.0 g/mL) by controlled gas generation or effective air entrapment within a hydration barrier [5].

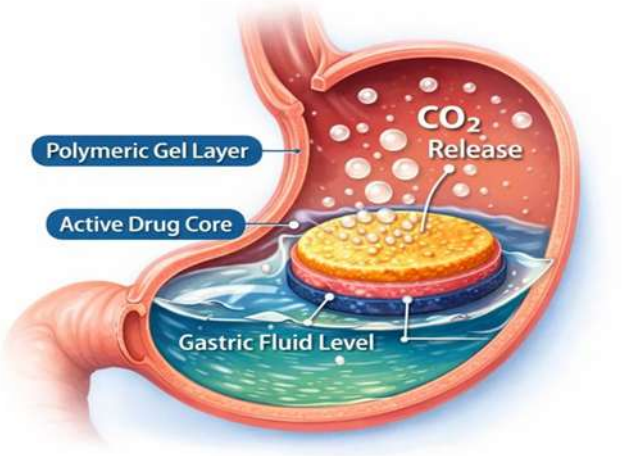

FIGURE: 1 Floating System

The two primary approaches are Effervescent Systems (using gas-generating components like sodium bicarbonate) and Non-Effervescent Systems (using highly porous matrices or swelling hydrocolloids to trap air [6].

Classification of floating system:

1. **Single Unit Floating Dosage Systems**
a) Effervescent system
b) Non-effervescent Systems
2. **Multiple Unit Floating Dosage Systems**
a) Effervescent Systems
b) Non-effervescent Systems
c) Hollow microspheres
3. **Raft forming system**

Table: 1 Good Candidates for Gastroretentive Drug Delivery System [7]

Sr. No.	Drug	Drug Category	Bioavailability (%)	Reason for Suitability in GRDDS
1	Verapamil	Calcium channel blocker	20–35	Narrow absorption window in upper GIT and extensive first-pass metabolism
2	Nifedipine	Calcium channel blocker	45–65	Short half-life and better absorption in stomach/upper intestine

3	Omeprazole	Proton pump inhibitor	35–60	Acid-labile drug, acts locally in stomach, benefits from prolonged gastric retention
4	Atenolol	Antihypertensive	40–50	Absorbed mainly in upper GIT; limited colonic absorption
5	Propranolol	Antihypertensive	4–26	High first-pass metabolism and narrow absorption window
6	Verapamil	Antihypertensive	18–35	Requires controlled release and prolonged gastric residence for improved absorption
7	Diltiazem	Calcium channel blocker	40	Short biological half-life and absorption mainly in upper GIT
8	Lidocaine	Local anaesthetic	35	Poor oral bioavailability due to first-pass metabolism; benefits from controlled release
9	Clarithromycin	Antibiotic	50	Used for *H. pylori* infection; requires prolonged gastric contact
10	Ramipril	ACE inhibitor	28	Absorbed in upper GIT and undergoes first-pass metabolism

Table 2 Gastroretentive Products Available in Market[8]

Brand Name	Drug	Type of Gastroretentive System	Company / Region
Valrelease®	Diazepam (15 mg)	Floating capsule	Hoffmann-La Roche, USA
Madopar® HBS (Prolopa® HBS)	Benserazide + L-dopa	Floating, CR capsule	Roche Products, USA
Liquid Gaviscon®	$Al(OH)_3$ + Mg carbonate	Effervescent floating liquid (antacid)	GlaxoSmithKline
Topalkan®	Al–Mg antacid	Floating liquid alginate	Pierre Fabre, France
Conviron®	Ferrous sulphate	Colloidal gel forming floating system	Ranbaxy, India
Cytotech®	Misoprostol (100 µg/200 µg)	Bilayer floating capsule	Pharmacia, USA
Cifran OD®	Ciprofloxacin (0.5–1 g)	Gas-generating floating system	Sun Pharma, India
Rantac OD®	Ranitidine (300 mg)	Floating system	J.B. Chemicals, India
Dompan SR®	Pantoprazole + Domperidone	Floating tablet	Medley, India
Creon 10000®	Pancreatin	Microcapsules	Abbott, India

MATERIALS AND METHODS [9-12].

3.1. Formulation Materials Selection

The **optimization** process begins with the critical selection of excipients that directly impact both buoyancy and release kinetics.

Table 3: Formulation Materials

Component	Examples	Classification	Critical Material Attribute (CMA)	Role / Impact on FDDS Performance
Active Ingredient (API)	Drug with narrow absorption window	Drug Substance	Solubility, dose, absorption window	Suitable for sustained release and gastric retention; benefits from prolonged gastric residence time

Polymeric Matrix Agents	HPMC, PEO	CMAs	Molecular weight, viscosity grade, concentration	Forms a strong gel layer controlling drug release; enables air entrapment necessary for tablet flotation
Gas-Generating Agents (Effervescent systems)	Sodium bicarbonate	CMAs	Type, particle size, concentration	Generates CO_2 on contact with gastric fluid; directly influences Floating Lag Time (FLT)
Lubricants & Glidants	Magnesium stearate, talc	CMAs	Concentration	Excess levels can hinder tablet hydration, delay gel formation, and increase FLT; therefore must be minimized

3.2. Manufacturing Process (Generalized Tablet Formulation) [14].

The tablet manufacturing method, typically direct compression or wet granulation, must be precisely controlled to ensure system functionality.

1. **Blending:** Ensuring uniform distribution of the API and excipients is paramount.
2. **Granulation (if applicable):** Process parameters like mixing time and solvent volume are CPPs influencing blend flowability and final tablet porosity.
3. **Compression:** The Compression Force is a Critical Process Parameter (CPP). It must be carefully optimized to provide sufficient mechanical strength (hardness) while maintaining adequate tablet porosity to allow for rapid fluid penetration and subsequent gas/air entrapment, which is essential for buoyancy.

3.3. Pre- and Post-Compression Characterization [15].

Systematic evaluation is performed to link input variables to initial quality outputs:

- **Pre-Compression:** Powder blend characteristics (e.g., bulk density, flowability) are measured to ensure process robustness.
- **Post-Compression (Physicochemical):** Mechanical strength (hardness, friability) is measured. These are Critical Quality Attributes (CQAs) directly influenced by the CPP, Compression Force.

Evaluation of Powder Blend[16]

a) Angle of Repose

Angle of repose is defined as the maximum angle possible between the surface of a powder heap and the horizontal plane. It is an indirect measure of powder flow property.

- Lower angle of repose → Better flow
- Measured by allowing powder to flow through a funnel onto a flat surface.

Formula:

$$\tan\,\theta = \frac{h}{r}$$

Where:

- h = height of powder heap
- r = radius of base

Angle of Repose (°)	Flow Property
< 30	Excellent
30–40	Good
> 40	Poor

b) Bulk Density

Bulk density represents the total density of powder, including interparticle void spaces.

Formula:

$$\text{Bulk Density} = \frac{\text{Weight of powder}}{\text{Bulk volume}}$$

- Depends on particle size, shape, and packing
- Important for tablet compression and uniform die filling

c) Percentage Porosity

Porosity indicates the void space within a powder bed and influences hardness, disintegration, and drug release.

Formula:

$$\%\text{Porosity} = \frac{\text{Void volume}}{\text{Bulk volume}} \times 100$$

or

$$\%\text{Porosity} = \frac{(\text{Bulk volume} - \text{True volume})}{\text{Bulk volume}} \times 100$$

2. Evaluation of Floating Tablets [17]

a) Measurement of Buoyancy Capability

Floating behavior is evaluated by measuring resultant weight in:

- Deionized water
- Simulated gastric fluid / simulated meal

Observation:

- High molecular weight polymers with slow hydration rate show better floating
- Floating is more prominent in simulated meal medium

b) In-Vitro Floating and Dissolution Behaviour

- Performed using USP dissolution apparatus
- USP allows dosage form to sink initially before paddle rotation
- Conventional methods are not always reliable for floating systems

Key Findings:

- Use of wire sinkers may inhibit swelling
- Ring/mesh assembly improves reproducibility
- Drug release depends on:
  - Swelling behavior
  - Surface exposure
  - Drug solubility in water

c) Weight Variation Test

Performed to ensure dose uniformity.

USP Method:

- Weigh 20 tablets individually
- Calculate average weight
- Compare individual weights with limits

Acceptance Criteria:

- Not more than 2 tablets outside limits
- No tablet deviates by more than twice the limit

d) Hardness and Friability

Hardness

Defined as force required to break a tablet under diametric compression.

Instruments used:

- Monsanto tester
- Pfizer tester
- Strong-Cobb tester

Friability

Measured using Roche Friabilator.

- Speed: **25 rpm**
- Revolutions: **100**
- Acceptable loss: **< 1%**

Formula:

$$\%\text{Friability} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

e) Particle Size Analysis & Surface Characterization

(For Floating Microspheres and Beads)

Parameter	Method
Particle size	Optical microscopy
Size distribution	Dry state measurement
Surface morphology	Scanning Electron Microscopy (SEM)

f) X-Ray / Gamma Scintigraphy

Used to track the position of dosage form in GIT.

- X-ray: Uses radio-opaque markers
- Gamma scintigraphy: Uses γ-emitting radionuclides
- Enables:
  - Gastric retention time estimation
  - Correlation with drug release

g) Pharmacokinetic Studies

Essential in-vivo evaluation parameter.

Key Parameters:

- T_{max}
- C_{max}
- AUC (Area Under Curve)

Observation:

- Floating systems show higher AUC and delayed Tmax
- Indicates improved bioavailability and prolonged gastric residence

RESULT & DISCUSSION [18-20].

4.1. The Systematic Development Paradigm for Optimization

The core of BDDDS development is the implementation of a systematic, science-driven approach to define the Design Space. This approach uses structured experimental designs to efficiently map the complex relationships between the input CMAs/CPPs and the final CQAs, allowing the formulator to select optimal manufacturing parameters.

The linkage between input and output is crucial for optimization:

- **Optimizing Buoyancy:** The Floating Lag Time (FLT), a key CQA, is optimized by adjusting the Polymer Concentration (CMA) and the Compression Force (CPP). A lower compression force may reduce FLT but also compromise mechanical strength, highlighting the need for optimization within the defined Design Space.
- **Optimizing Drug Release:** The dissolution profile (CQA) is primarily controlled by the Viscosity Grade of the Polymer (CMA) and its concentration. Higher viscosity grades or concentrations generally lead to a thicker, stronger gel layer, resulting in slower, more sustained release kinetics.

4.2. In Vitro Performance Evaluation

The optimized formulation must demonstrate functionality and consistency through rigorous *in vitro* testing:

4.2.1. Buoyancy Test

This test directly confirms the success of the optimization regarding gastric retention. The FLT must be rapid (ideally < 1-5 minutes) to prevent premature emptying, and the Total Floating Duration (TFT) must meet the sustained retention target (typically > 8-12 hours).

4.2.2. Swelling Index and Water Uptake

The Swelling Index must be optimized to ensure it provides sufficient volume increase for air entrapment while forming a controlled-release gel barrier. The rate and extent of swelling are measured over time to ensure consistency across batches[21].

4.2.3. Drug Release Studies

Dissolution testing confirms that the release profile adheres to the target requirements. The data are rigorously analyzed using kinetic models (Korsmeyer-Peppas and Higuchi) to ensure the mechanism of release is understood, predictable, and optimized for sustained action [22].

CONCLUSION

The development of Buoyancy-Driven Drug Delivery Systems for drugs with narrow absorption windows is fundamentally an optimization challenge. The adoption of a systematic, quality-focused approach is mandatory to navigate the complex interdependencies between formulation inputs and performance outputs. By defining a robust Design Space and precisely controlling CMAs and CPPs, formulators can consistently produce dosage forms that achieve reliable flotation, optimal swelling, and highly predictable sustained release. This strategic approach ensures the maximum therapeutic benefit for the patient in the long-term management of chronic diseases.

ACKNOWLEDGEMENT

The authors wish to express their profound gratitude to the Head of the Department of Pharmaceutics, Sharda School of Pharmacy, for providing the necessary laboratory facilities and administrative support to conduct the research that forms the foundation of this review. We also thank the Gujarat Technological University (GTU) for the continued opportunity and resources provided to pursue this area of specialization.

REFERENCES

1. Singh, S., Gulati, M., & Kaur, T. (2021). Floating drug delivery systems: A comprehensive review of recent progress and advancements. Journal of Drug Delivery Science and Technology, 63, 102500.
2. Sreeja, C., Suseela, C., & Rao, A. S. (2022). Gastroretentive drug delivery systems: A detailed review on recent patents and formulation strategies. Future Journal of Pharmaceutical Sciences, 8(1), 1-17.
3. Chobanian, A. V., Bakris, G. L., Black, H. R., et al. (2003). The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC 7). JAMA, 289(19), 2560–2572.
4. Alagawany, M., El-Sayed, O. M., & Khalil, R. M. (2020). Novel approaches for enhancing the oral bioavailability of Calcium Channel Blockers using gastroretentive technology: A systematic review. European Journal of Pharmaceutical Sciences, 143, 105151.
5. Kushkiwala, A.M., Zankhwala, F.M., Patel, M.D. and Raval, A.M. (2024) ‘Flurbiprofen

loaded ethosomal gel: Design, optimization, and anti-inflammatory activity', International Journal of Research and Analytical Reviews (IJRAR), 11(4), pp. 709–713.
6. Mrs. Fayeja M. Zankhwala, Mr. Amar M. Raval, Ms. Asefabanu M. Kushkiwala, Mr. Sumit P. Sarvaiya, Ms. Komal K. Raval, Ms. Nikitabahen J. Thakar, Ms. Shilpa V. Barjod, Formulation and evaluation of optimized polymer blends for diclofenac diethylamine transdermal system. The Review of Diabetic Studies, 21(S9), 701–708.
7. Vaghasiya, H., Pandya, P., & Jethava, A. (2023). Optimization of floating matrix tablets: A systematic approach using experimental design. Pharmaceutical Development and Technology, 28(6), 661-671.
8. Shinde, S., Tadwee, I. and Shahi, S., 2011. Gastro retentive drug delivery system: A review. International Journal of Pharmaceutical Research & Allied Sciences, 1(1), pp.1–13.
9. Kaur, S., Rawat, H., & Sharma, M. (2021). Hydrogel based gastroretentive delivery systems: An overview of polymers and formulation techniques. Journal of Drug Delivery Science and Technology, 61, 102179.
10. Garg, R., & Gupta, G. D. (2008). Progress in controlled gastroretentive delivery systems. Tropical Journal of Pharmaceutical Research, 7(3), 1085–1096.
11. Higuchi, T. (1963). Mechanism of sustained-action medication: Theoretical analysis of rate of release of solid drugs dispersed in solid matrices. Journal of Pharmaceutical Sciences, 52(12), 1145–1149.
12. ICH Harmonised Tripartite Guideline (2003). Stability Testing of New Drug Substances and Products Q1A(R2). International Conference on Harmonisation, Geneva.
13. ICH Harmonised Tripartite Guideline (2005). Validation of Analytical Procedures: Text and Methodology Q2(R1). International Conference on Harmonisation, Geneva.
14. Indian Council of Medical Research (ICMR). (2020). Hypertension in India: Epidemiology and public health challenges. New Delhi: ICMR.
15. Khan, K. A. (1975). The concept of dissolution rate and the effect of parameters on the rate. Acta Pharmaceutica Jugoslavica, 25(3), 111–122.
16. Korsmeyer, R. W., Gurny, R., Doelker, E., Buri, P., & Peppas, N. A. (1983). Mechanisms of solute release from porous hydrophilic polymers. International Journal of Pharmaceutics, 15(1), 25–35.
17. El-Gizawy, S. A., Elgindy, N. A., & Mostafa, H. (2024). Advanced floating techniques for enhancing gastric residence time: Formulation and characterization. International Journal of Pharmaceutics, 650, 123652.
18. Moës, A. J. (1993). Dosage forms and GI transit problems. International Journal of Pharmaceutics, 92(1-3), 85–94.
19. Ali, J., Ahmed, M., & Abbas, M. (2023). Role of systematic product development in designing novel drug delivery systems. Current Pharmaceutical Design, 29(15), 1318-1329.
20. Zhang, W., Chen, J., & Li, Y. (2022). Floating drug delivery systems for improved oral bioavailability: Recent trends and commercialization potential. Journal of Controlled Release, 347, 45-56.
21. Shah, V. P., Tsong, Y., Sathe, V., & Liu, J. P. (1995). In vitro dissolution profile comparison—Statistics and analysis of the similarity factor, f2. Pharmaceutical Research, 12(suppl 3), 659–664.
22. Hassan, A. I., Ibrahim, F. E., & Hamza, M. Y. (2024). Systematic approach to the

formulation and optimization of gastroretentive dosage forms. Asian Journal of Pharmaceutical Sciences, 19(2), 100778.

23. World Health Organization (WHO). (2024). Hypertension fact sheet. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/hypertension

HOW TO CITE: Patel Nrup, Amar Raval, Gastro Retentive Drug Delivery System: A Review, Int. J. of Pharm. Sci., 2026, Vol 4, Issue 1, 734-742. https://doi.org/10.5281/zenodo.18186802