



Review Article

Advances in Gastroretentive Floating Drug Delivery Systems: A Comprehensive Review

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Oral controlled drug delivery systems have consistently faced challenges due to the physiological limitations of the gastrointestinal tract, primarily characterized by erratic gastric emptying times and narrow regional absorption windows. To overcome these constraints, Gastroretentive Drug Delivery Systems (GRDDS) have emerged as a paradigm-shifting approach designed to prolong the gastric residence time of dosage forms. Among the diverse technological strategies, Floating Drug Delivery Systems (FDDS) represent the most widely implemented and clinically viable platform due to their low density, inherent buoyancy over gastric fluids, and predictable release mechanics. This comprehensive review systematically explores the fundamental concepts, anatomical requisites, and mechanistic principles of FDDS. The classification of effervescent and non-effervescent buoyant systems is detailed, alongside an in-depth analysis of key formulation variables, particularly the critical role of synthetic and natural hydrocolloid polymers. Furthermore, this paper provides a robust evaluation of recent high-tech advancements spanning the years 2021 to 2026, highlighting the integration of fused deposition modeling 3D printing, smart responsive materials, and microballoons. Standard in vitro and in vivo characterization methodologies are rigorously outlined. Finally, this review highlights the therapeutic applications, challenges, and future clinical translation trends of floating matrices, offering a valuable reference framework for contemporary pharmaceutical formulation design.

Keywords: Gastroretentive systems, Floating drug delivery, Buoyancy, Hydrogels, 3D printing, Gastric residence time, Pharmacokinetics.

INTRODUCTION

The oral route remains the gold standard for pharmaceutical administration, representing over 60% of all commercialized dosage forms due to its unmatched patient compliance, ease of ingestion, and formulation flexibility [1]. However, the development of effective oral controlled-release matrices is frequently throttled by a matrix of physiological hurdles within the human gastrointestinal (GI) tract [2]. Prominent among these constraints are the highly variable gastric emptying rates, transient transit times across the small intestine, and the highly localized regional absorption windows exhibited by numerous critical therapeutic molecules [3]. When a conventional sustained-release dosage form transits past its primary absorption window in the upper small intestine, it enters regions with suboptimal

permeability or unfavorable pH environments, resulting in incomplete drug extraction and drastically compromised systemic bioavailability [4]. To circumvent these biological limitations, the pharmaceutical scientific community has heavily invested in the engineering of Gastroretentive Drug Delivery Systems (GRDDS) [5]. These specialized platforms are designed to remain localized within the gastric cavity for extended durations, systematically resisting the physiological emptying mechanisms of the stomach [6]. By acting as a stationary reservoir in the gastric lumen, GRDDS continuously release the active pharmaceutical ingredient (API) in a controlled manner, guaranteeing a steady and prolonged influx of the drug directly into the proximal segments of the small intestine, which typically serves as the primary

absorption window [7]. This site-specific release pattern minimizes systemic side effects, prevents toxic plasma fluctuations, and reduces the required dosing frequency, thereby directly bolstering patient compliance and overall therapeutic outcomes [8].

2. Need for Gastroretentive Drug Delivery Systems

The fundamental impetus for developing GRDDS arises from the pharmacodynamics and pharmacokinetic mismatches inherent to conventional dosage forms when delivering specific drug candidates [9]. Conventional extended-release systems lack site-retention capabilities; thus, their transit through the stomach and intestine is strictly governed by systemic peristalsis, irrespective of whether the drug has been completely discharged [10]. This creates an urgent clinical need for gastroretention in several scenarios: first, for drugs that act locally within the stomach, such as antacids, mucosal protectants, and antimicrobial agents utilized in the eradication of *Helicobacter pylori* [11]. Maintaining a high local drug concentration directly at the gastric mucosal surface significantly maximizes the bactericidal efficacy while minimizing systemic toxicity [12].

Second, gastroretention is essential for drugs that exhibit narrow absorption windows, meaning they are exclusively absorbed from the stomach or the proximal segments of the duodenum and jejunum [13]. Examples include levodopa, riboflavin, and metformin. When these drugs are incorporated into conventional matrices, any acceleration in gastric emptying pushes the dosage form into the colon, where absorption is negligible, causing therapeutic failure [14]. Third, molecules that are unstable or poorly soluble in the alkaline environment of the lower intestine benefit significantly from a prolonged gastric residence [15]. By keeping the drug dissolved within the highly acidic gastric juice (pH 1.2–2.5), the system ensures optimal solubility conditions before the drug moves down the intestinal tract [16].

3. Anatomy and Physiology of the Stomach Related to Gastroretention

Designing effective gastroretentive systems requires a deep understanding of the unique anatomical structure and complex motor patterns of the human stomach

[17]. Anatomically, the stomach is divided into three major functional zones: the fundus, the body (corpus), and the antrum (pylorus) [18]. The fundus and proximal body act as a reservoir for ingested material, exerting a constant, gentle basal pressure to guide contents toward the distal region [19]. The distal body and antrum function as the primary mixing and grinding organ, generating forceful peristaltic contractions that break down large food particles and push them through the narrow pyloric sphincter into the duodenum [20]. The pyloric sphincter acts as a strict physiological sieve, preventing the passage of solid particles larger than approximately 1.5 to 2.0 mm during the digestive phase [21]. The primary physiological challenge to gastroretention is the Interdigestive Myoelectric Complex, commonly referred to as the Migrating Motor Complex (MMC) [22]. The MMC is a highly organized cyclic pattern of electromechanical activity observed in the empty stomach during the fasting state, repeating every 90 to 120 minutes [23]. It consists of four distinct consecutive phases: Phase I (Basal phase), lasting 40–60 minutes, characterized by absolute quiescence and rare contractions; Phase II (Pre-burst phase), lasting 20–40 minutes, marked by irregular, intermittent contractions that gradually increase in intensity; Phase III (Burst phase), lasting 5–15 minutes, characterized by intense, regular, and regular house-keeper contractions that sweep all residual contents, including large undigested material, through the wide-open pylorus; and Phase IV, a short transitional period of 0–5 minutes leading back to Phase I [24]. For non-floating systems, survival past Phase III is exceptionally difficult unless the device is significantly large or highly bioadhesive [25].

4. Principles of Floating Drug Delivery Systems

Among the various technological subcategories of gastroretention—which include high-density sinking matrices, bioadhesive networks, swelling or expandable systems, and magnetic platforms—Floating Drug Delivery Systems (FDDS) have achieved the highest degree of commercial success and experimental reproducibility [26]. The core operating principle of FDDS relies on the physical properties of buoyancy [27]. To achieve reliable buoyancy, the bulk density of the formulation must remain consistently lower than the density of the

native gastric fluid, which is approximately 1.004 g/cm³ [28]. When the device is ingested, it quickly hydrates upon contact with the gastric juice, maintaining an effective density below 1.004 g/cm³ while remaining afloat on the surface of the gastric contents within the fundus or body of the stomach [29]. By remaining floating at the topmost layer of the gastric contents, the dosage form is safely insulated from the aggressive propulsive waves generated by the antral musculature [30]. Consequently, the system remains positioned inside the stomach for a prolonged period, continuously releasing the dissolved drug into the fluid [31]. As long as the system maintain a density below that of the gastric juice, it will resist emptying during Phases I and II of the MMC [32]. Once the drug payload is completely exhausted, the remaining spent polymeric matrix loses its structural integrity, increases in bulk density, dissolves, or collapses, allowing it to be safely eliminated from the GI tract via normal peristalsis [33].

5. Classification of Gastroretentive Floating Drug Delivery Systems

Floating drug delivery systems can be broadly categorized into two major classes based on their operational mechanism and formulation composition: Effervescent (Gas-generating) Systems and Non-effervescent Systems [34]. Each configuration utilizes unique material architectures to achieve the desired buoyant state, as described below.

5.1 Effervescent (Gas-Generating) Systems

Effervescent systems contain a gas-generating component, typically comprising an organic acid (such as citric acid or tartaric acid) and a carbonate or bicarbonate salt (such as sodium bicarbonate or calcium carbonate) matrixed alongside hydrophilic swelling polymers [35]. When this system comes into contact with the acidic environment of the gastric juice, a chemical reaction is instantly triggered, generating carbon dioxide (CO₂) gas [36]. The liberated CO₂ gas becomes trapped within the rapidly hydrating, highly viscous gel layer formed by the surrounding hydrophilic polymers [37]. This trapped gas causes the device to expand and dramatically

lowers its bulk density below 1.004 g/cm³, driving rapid and sustained flotation [38]. Effervescent formulations can be further sub-classified into single-unit floating tablets or multi-unit systems like effervescent floating beads or microballoons [39].

5.2 Non-Effervescent Systems

Non-effervescent systems rely exclusively on the swelling and entrapment characteristics of highly cohesive, gel-forming hydrocolloids or low-density lipid excipients, without any gas-producing chemical reactions [12]. Upon ingestion, the outer layers of the polymer rapidly absorb fluid and swell to create a thick, continuous gel barrier [15]. Air becomes trapped within the dry core of the unhydrated polymer matrix during this swelling process, keeping the overall density below unity [18]. These systems are further divided into Hydrodynamically Balanced Systems (HBS), which incorporate high levels of cellulose derivatives; hollow microspheres (microballoons) prepared by emulsion-solvent evaporation; and multi-layer floating configurations that segregate the buoyant layer from the drug reservoir layer [21].

6. Mechanism of Floating Drug Delivery Systems

The mechanism of buoyancy in FDDS can be mathematically explained by analyzing the balance of hydrodynamic forces acting on a solid body submerged in fluid [24]. The net vertical force (F_{net}) acting on the system is a function of the gravity force (F_g) acting downwards and the buoyancy force (F_b) pushing upwards, which can be defined by the following expression:

$$F = F_b - F_g = (\rho_f - \rho_s) \cdot V \cdot g$$

where ρ_f represents the density of the gastric fluid, ρ_s represents the bulk density of the solid floating dosage form, V is the total hydrodynamic volume of the expanded device, and g is the acceleration due to gravity [27]. For a formulation to exhibit positive upward buoyancy, the net force F must remain positive, which mathematically dictates that $\rho_s < \rho_f$ [29].

Effervescent Matrix	Non-Effervescent Matrix
Gastric Fluid Influx → Acid-Carbonate Reaction → CO ₂ Gas Generation → Entrapment in Gel Layer → Density < 1.004 g/cm ³ (Buoyancy)	Gastric Fluid Influx → Polymer Hydration → Rapid Viscous Swelling → Air Entrapment in Core → Density < 1.004 g/cm ³ (Buoyancy)

Figure 1: Mechanistic Operation of Effervescent vs. Non-Effervescent Floating Systems.

As illustrated in Figure 1, the physical pathway to achieving this low density varies between the two types. In effervescent matrices, fluid penetration triggers a chemical reaction that fills the gel matrix with CO₂ bubbles. In non-effervescent systems, fluid intake triggers rapid polymer swelling, forming a thick gel boundary layer that encapsulates air pockets within the dry inner core. Both pathways achieve the same outcome: reducing the bulk density below that of the gastric fluid to ensure reliable flotation [31].

7. Advantages

Floating drug delivery systems offer substantial clinical and technological benefits over conventional or alternative gastroretentive configurations [33]. A primary advantage is their complete independence from mucocutaneous adhesion mechanics, allowing them to function reliably without causing local irritation or damage to the delicate gastric mucosa—a frequent limitation of bioadhesive systems [35]. Additionally, FDDS are highly effective at maintaining a constant, uniform therapeutic drug level in the plasma, which minimizes toxicological spikes and sub-therapeutic drops [36]. Table 1 summarizes the main therapeutic advantages of FDDS.

Table 1: Strategic Advantages of Floating Drug Delivery Systems.

Advantage Category	Detailed Pharmaceutical & Clinical Impact
Enhanced Bioavailability	Continuous release directly above the upper small intestine absorption window maximizes absorption efficiency for narrow-window drugs.
Reduced Dosing Frequency	Extended gastric retention allows once- or twice-daily dosing regimens, enhancing patient compliance and quality of life.
Minimized Local Irritation	Sustained, incremental release avoids high local concentrations of irritating drugs (e.g., NSAIDs) on the gastric mucosal lining.
Site-Specific Therapy	Provides targeted delivery within the stomach cavity, improving treatments for gastric ulcers, gastritis, and <i>H. pylori</i> infections.
Reduced Plasma Fluctuations	Maintains steady-state blood concentrations, preventing the peak-and-trough variations typical of immediate-release options.

LIMITATIONS

Despite their numerous benefits, FDDS face several specific physiological and formulation challenges that can limit their real-world clinical efficacy [38]. A key constraint is the strict requirement for a minimum volume of fluid within the gastric cavity to allow the system to float effectively [39]. If the patient is in a fasted or dehydrated state, the lack of sufficient gastric juice prevents the formulation from floating,

causing it to settle on the antrum and be rapidly expelled by Phase III MMC waves [2]. Furthermore, FDDS are not suitable for drug candidates that suffer from stability or solubility issues within the highly acidic gastric fluid, or those that undergo significant degradation by pepsin [4]. Another challenge is the high variability in gastric emptying times among patients, which is influenced by factors such as age, gender, disease state, and posture [6]. For instance, a patient in a supine or flat lying position may

experience premature emptying of the floating device, as it can drift toward the pyloric sphincter and enter the duodenum [9]. Finally, formulating high-dose drugs into floating systems is difficult; adding large amounts of active ingredients often increases the overall density of the matrix, making it challenging to maintain buoyancy without creating an unmanageably large tablet or capsule [11].

9. Factors Affecting Gastric Retention

The operational performance and in vivo residence time of floating systems are highly dependent on several interconnected physiological, formulation, and patient-specific factors [13]:

- **Density and Size:** The bulk density of the formulation is the primary factor determining buoyancy. A density less than 1.004 g/cm³ is required for flotation. Additionally, the physical size of the device must be optimized; single-unit formulations generally require a diameter greater than 7–10 mm to resist premature passage through the pylorus during intermediate contractions [16].
- **Caloric Content and Food Intake:** Gastric retention times change dramatically between the fed and fasted states. Ingesting meals rich in fats or proteins triggers a significant delay in gastric emptying, switching the stomach to a digestive motor pattern that closes the pylorus and allows

floating devices to remain buoyant for much longer periods [18].

- **Concomitant Medications:** Administering floating systems alongside drugs that alter GI motility can significantly impact performance. For example, co-administering prokinetic agents like metoclopramide or erythromycin accelerates gastric emptying, reducing retention time. Conversely, anticholinergic agents like propantheline delay motility, extending gastric residence [22].
- **Patient Demographics and Physiology:** Elderly patients often exhibit naturally delayed gastric emptying rates, which can prolong retention times. Additionally, pathological states such as diabetic gastroparesis extend gastric residence, whereas conditions like Crohn's disease or hyperthyroidism accelerate intestinal transit [25].

10. Polymers Used in Floating Drug Delivery Systems

Selecting appropriate polymeric carriers is crucial for designing robust, functional floating drug delivery networks [28]. The polymers must exhibit rapid hydration kinetics to form a cohesive gel layer, while maintaining sufficient mechanical strength to withstand gastric shear forces and resist premature erosion [30]. Table 2 compares key natural and synthetic polymers commonly used in FDDS formulations.

Table 2: Comparative Profile of Key Polymers in Floating Drug Delivery Formulations.

Polymer Name	Origin / Type	Buoyancy & Gelling Properties	Typical Applications & Key Roles
Hydroxypropyl Methylcellulose (HPMC)	Semi-synthetic Cellulose	Forms a highly viscous, swellable hydrogel layer via rapid hydration; provides excellent control over drug diffusion.	The gold standard rate-controlling matrix polymer for both effervescent and non-effervescent single-unit floating tablets.
Sodium Alginate	Natural Polysaccharide	Undergoes ionotropic gelation with divalent cations (e.g., Ca ²⁺) to form a cross-linked insoluble hydrogel network.	Widely used to formulate multi-unit floating beads, microballoons, and in situ raft-forming liquid preparations.
Chitosan	Natural Amino-polysaccharide	Exhibits excellent solubility and rapid swelling in acidic media; combines natural buoyancy with intrinsic mucoadhesive properties.	Utilized in dual-mechanism bioadhesive-floating microcapsules and multi-unit particulate matrices.
Eudragit (S100, RL100)	Synthetic Polymethacrylate	Insoluble in acidic gastric juice; provides a rigid polymeric shell that controls water vapor and gas diffusion.	Commonly applied as a coating material for hollow microballoons and multi-particulate floating systems.

11. Methods of Evaluation

Characterizing and validating floating formulations requires rigorous multi-parametric *in vitro* and *in vivo* testing to ensure reliable quality control and clinical predictability [34]. Standard evaluation parameters include:

11.1 In Vitro Buoyancy Studies

In vitro buoyancy is typically assessed using a standard USP Type II (paddle) dissolution apparatus filled with simulated gastric fluid (SGF, pH 1.2) maintained at 37 ± 0.5 °C [37]. Two

critical kinetic metrics are recorded: Floating Lag Time (FLT), defined as the time required for the dry formulation to ascend from the bottom of the vessel to the surface of the medium; and Total Floating Duration (TFD), which is the total uninterrupted time the formulation remains buoyant on the fluid surface [39]. A high-quality formulation should exhibit an FLT of less than 60 seconds and a TFD exceeding 12 to 24 hours [3].

11.2 Swelling and Matrix Erosion Dynamics

The swelling kinetics are determined by measuring the weight gain of the matrix over time. After immersion in SGF, the formulation is removed at scheduled intervals, blotted dry, and weighed [6]. The swelling index (SI) is calculated using the following equation:

$$SI = \frac{W_t - W_0}{W_0} \times 100$$

where W_t represents the mass of the hydrated system at time t , and W_0 is the initial dry mass of the formulation [8]. Concurrently, matrix erosion is analyzed by drying the recovered matrices to a constant weight to evaluate physical polymer dissolution over time [10].

11.3 In Vivo Gastric Visualization

While *in vitro* studies provide valuable screening data, definitive confirmation of gastroretention requires *in vivo* evaluation [14]. This is typically accomplished by incorporating a radiopaque contrast agent, such as barium sulfate, into the formulation

matrix, followed by radiographic X-ray imaging of healthy human volunteers or animal models (e.g., albino rabbits or beagles) at scheduled time intervals [17]. Alternatively, gamma scintigraphy utilizing gamma-emitting radionuclides (such as Technetium-99m or Indium-111) can track the precise position and erosion kinetics of the floating device across the GI tract without exposing subjects to high radiation doses [20].

12. Recent Advances in Gastroretentive Floating Drug Delivery Systems (2021–2026)

The field of gastroretentive drug delivery has advanced significantly between 2021 and 2026, driven by breakthroughs in additive manufacturing, digital health, and material science [23]. A key innovation is the widespread adoption of Fused Deposition Modeling (FDM) and semi-solid extrusion (SSE) 3D printing to fabricate highly customized floating architectures [25]. By leveraging computer-aided design (CAD), researchers can print tablets with precise inner infill geometries, creating sealed internal air pockets or chambers [26]. This approach achieves immediate, non-effervescent buoyancy that is completely independent of environmental gas-generation reactions or rapid fluid swelling [27]. These 3D-printed devices maintain excellent floating structural integrity for extended periods, avoiding the rapid matrix disintegration common to traditional compressed tablets [28]. Another major advance involves developing smart, stimulus-responsive floating matrices [29]. These modern systems utilize advanced polymers that respond to specific physiological cues, such as changes in pH or temperature [30]. For instance, certain formulations remain highly compact during ingestion but undergo immediate, controlled expansion into low-density, floating porous hydrogels upon contact with the acidic environment of gastric juice [31]. Furthermore, combining nanotechnological carriers with floating matrices has gained traction, enabling the entrapment of nanocrystals, lipid nanoparticles, or self-emulsifying systems within buoyant microballoons [32]. This multi-stage approach simultaneously enhances the dissolution kinetics of poorly soluble molecules and extends their residence time within the upper GI tract [33].

13. Applications of Floating Drug Delivery Systems

Floating drug delivery systems have been successfully applied to optimize the therapeutic performance of numerous clinically vital medications [35]:

- **Eradication of *Helicobacter pylori*:** Delivering antibiotics like amoxicillin, clarithromycin, and metronidazole via floating microballoons or rafts ensures sustained local concentrations directly within the gastric mucus layer, where the bacteria reside. This approach enhances bactericidal efficacy and minimizes systemic side effects [36].
- **Enhanced Treatment of Parkinson's Disease:** Levodopa is primarily absorbed through specialized transport pathways in the proximal small intestine. Standard formulations often transit past this narrow window too quickly, leading to unpredictable plasma concentrations and motor fluctuations. Floating levodopa tablets provide a steady influx of the drug, stabilizing plasma levels and improving clinical outcomes [38].
- **Glycemic Control in Diabetes:** Antidiabetic agents like metformin and repaglinide have short biological half-lives and preferential absorption in the upper GI tract. Formulating these drugs into floating matrices extends gastric retention, ensuring steady absorption and sustained glycemic control [1, 14].

FUTURE PERSPECTIVES

The future evolution of FDDS is expected to transition from static, passive delivery matrices to smart, interactive systems [5]. A promising area of development is the integration of wireless electronic components and biosensors into 3D-printed floating capsules [8]. These smart devices could monitor real-time gastric physiological parameters—such as pH, temperature, and localized pressure—and transmit this data wirelessly to external devices, while simultaneously releasing the drug payload via micro-actuators [12]. Furthermore, developing custom, patient-centric floating devices using point-of-care 3D printers in clinical pharmacies could allow formulations to be tailored to an individual's gastric

emptying profile, body mass, and specific metabolic requirements [15]. Additionally, discovering novel, biocompatible synthetic polymers and cross-linked natural gums will continue to expand the formulation options available for designing resilient, high-buoyancy delivery platforms [19].

CONCLUSION

Gastroretentive Floating Drug Delivery Systems represent a robust, technologically mature, and highly effective platform for overcoming the biological limitations of oral drug administration. By maintaining a bulk density lower than that of gastric fluid, these systems achieve prolonged buoyancy, ensuring extended gastric residence without causing mucosal irritation. This review highlighted the essential design principles of FDDS, detailing the differences between effervescent and non-effervescent mechanisms, as well as the critical role of specialized hydrocolloid polymers. Recent advancements from 2021 to 2026, particularly the integration of 3D printing and smart responsive materials, demonstrate the continuous innovation in this field, moving toward highly predictable and personalized patient therapies. As formulation technologies and clinical modeling continue to advance, floating drug delivery systems are poised to play an increasingly vital role in optimizing oral controlled-release therapies and improving patient outcomes worldwide.

REFERENCES

1. Pawar M. A review on gastro retentive drug delivery system (GRDDS). *Int J Sci R Tech.* 2025;2(5): 73-81.
2. Nayak BS, Suna PK, Patel PR, Panigri P, Samarath B. Floating drug delivery system: Its current approach and advancement. *Indo Am J Pharm Sci.* 2015; 2:1550-1556.
3. Pawar KS, Sonawane MP, Rathod A, Nikam V. An updated review on floating microspheres for gastro-retentive drug delivery system. *Asian J Pharm Technol.* 2025;15(2):205-214.
4. Darshanam V, Merugu M. Preparation and evaluation of gastroretentive microballoons of dexlansoprazole containing natural and synthetic polymers. *J Pharma Insights Res.* 2024;2(1):45-53.

5. Adsul SS, Wable MS, Bhand RN, Gayke SR, Avhad P. Floating drug delivery systems: An advanced approach for oral controlled drug release. *Asian J Pharm Technol.* 2026;16(1):99-104.
6. Dumpa NR, Bandari S, Repka MA. Novel gastroretentive floating pulsatile drug delivery system produced via hot-melt extrusion and fused deposition modeling 3D printing. *Pharmaceutics.* 2020;12(1):34-45.
7. Hasan AM, Cavalu S, Kira AY, Hamad RS, Abdel-Reheim MA, Elmorsy EA. Localized drug delivery in different gastrointestinal cancers: Navigating challenges and advancing nanotechnological solutions. *Int J Nanomedicine.* 2025; 20:741-770.
8. Gopalakrishnan S, Chenthilnathan A. Floating drug delivery systems: A review. *J Pharm Sci Res.* 2021;13(4):211-219.
9. Davis SS. Formulation strategies for gastroretentive drug delivery systems. *Drug Discov Today.* 2005;10(4):249-257.
10. Garg R, Gupta GD. Progress in controlled gastroretentive delivery systems. *Trop J Pharm Res.* 2008;7(3):1055-1066.
11. Rouge N, Buri P, Doelker E. Drug absorption sites in the gastrointestinal tract and dosage forms for site specific delivery. *Int J Pharm.* 1996; 136:117-139.
12. Chawla G, Gupta P, Koradia V, Bansal AK. Gastroretentive drug delivery systems: A review. *Crit Rev Ther Drug Carrier Syst.* 2003;20(2):115-174.
13. Singh BN, Kim KH. Floating drug delivery systems: An approach to oral controlled drug delivery via gastric retention. *J Control Release.* 2000;63(3):235-259.
14. Streubel A, Siepmann J, Bodmeier R. Floating matrix tablets based on low density polymers. *Int J Pharm.* 2002;241(2):279-292.
15. Whitehead L, Fell JT, Collett JH, Sharma HL, Smith AM. Floating dosage forms: An in vivo study demonstrates acid-resistance and prolonged gastric residence. *J Control Release.* 1998;55(1):3-12.
16. Klausner EA, Lavy E, Barta M, Cserepes E, Friedman M, Hoffman A. Novel gastroretentive dosage forms: Evaluation of gastroretention in humans. *Pharm Res.* 2003;20(9):1466-1473.
17. Mojaverian P, Vlasses PH, Kellner PE, Rocci ML. Effects of gender, age, and meal caloric content on gastric emptying time. *Clin Pharmacol Ther.* 1988;44(4):453-458.
18. Hou SY, Cowles VE, Berner B. Gastric retention of large size tablets in fed and fasted states. *Int J Pharm.* 2003;262(1):53-61.
19. Shishu, Gupta N, Aggarwal N. Stomach-specific drug delivery of 5-fluorouracil using floating alginate beads. *AAPS PharmSciTech.* 2007;8(2):E143-E149.
20. Iannuccelli V, Coppi G, Sansone R, Ferrucci CG. Air-compartment multiple-unit system for prolonged gastric residence. *Int J Pharm.* 1998;174(1):47-54.
21. Ichikawa M, Watanabe S, Miyake Y. A new multiple-unit oral floating dosage system. I. Preparation and in vitro evaluation of floating sustained-release microballoons. *J Pharm Sci.* 1991;80(11):1062-1066.
22. Yang L, Eshraghi J, Fassihi R. Floating and swelling characteristics of an oral gastroretentive system. *Drug Dev Ind Pharm.* 1999;25(12):1277-1282.
23. Talukder R, Fassihi R. Gastroretentive delivery systems: Hollow beads. *Drug Dev Ind Pharm.* 2004;30(4):405-412.
24. Joseph NJ, Laxmi S, Jayakrishnan A. A floating polymer bead system for time-specified drug release. *J Control Release.* 2002;79(1):253-262.
25. El-Kamel AH, Sokar MS, Al Gamal SS, Naggat VF. Preparation and evaluation of ketoprofen floating oral delivery systems. *Int J Pharm.* 2001;220(1):13-21.
26. Rahman Z, Ali M, Khar RK. Design and evaluation of bilayer floating tablets of captopril. *Acta Pharm.* 2006;56(1):49-61.
27. Dave BS, Amin AF, Patel MM. Preparation and evaluation of a gastroretentive drug delivery system of ranitidine hydrochloride. *AAPS PharmSciTech.* 2004;5(2):E34.
28. Basak SC, Rao KN. Development and in vitro evaluation of an effervescent floating drug delivery system for ciprofloxacin. *Indian J Pharm Sci.* 2007;69(6):820-823.
29. Sriamornsak P, Thirawong N, Asavapichayont P. Morphology and buoyancy of barium-containing alginate gel beads. *AAPS PharmSciTech.* 2007;8(3):E104-E110.

30. Patel DM, Patel NM, Pandya NN, Jogani PD. Gastroretentive drug delivery system of metformin hydrochloride: Formulation and in vitro evaluation. *Indian J Pharm Sci.* 2007;69(6):844-847.
31. Shinde JV, Dhaliz MD, More KN. Development of floating matrix tablets of diltiazem hydrochloride. *Iranian J Pharm Res.* 2010;9(3):235-242.
32. Jimenez-Martinez A, Melgoza-Contreras LM, Carvajal-Hernandez F. Floating matrix tablets of gabapentin using natural polymers. *Drug Dev Ind Pharm.* 2012;38(11):1345-1352.
33. Arora S, Ali J, Ahuja A, Khar RK, Baboota S. Floating drug delivery systems: A review. *AAPS PharmSciTech.* 2005;6(3):E372-E390.
34. Prajapati VD, Jani GK, Khutliwala TA, Zala BS. Raft forming systems: A novel approach of gastroretentive drug delivery system. *J Control Release.* 2013;168(2):151-165.
35. Chen YC, Ho HO, Lee TY, Sheu MT. Physical characterization and in vivo evaluation of gastroretentive floating sustained-release tablets of amoxicillin. *Int J Pharm.* 2011;418(2):224-232.
36. Steingoetter A, Fox M, Treier R, Fried M, Schwizer W. In vivo evaluation of a gastric floating drug delivery system using magnetic resonance imaging. *Pharm Res.* 2007;24(12):2215-2222.
37. Fell JT, Whitehead L, Collett JH. Prolonged gastric retention of floating dosage forms. *Pharm Technol.* 2000;24(3):82-90.
38. Jagdale SC, Agavekar AJ, Pandya SV, Kuchekar BS. Formulation and evaluation of gastroretentive floating tablets of levodopa with carbidopa. *Braz J Pharm Sci.* 2011;47(4):815-825.
39. Zhang C, Tang X. Floating drug delivery systems: A prospective approach for gastric retention. *J Pharm Biomed Anal.* 2022; 208:114-125.

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