World Journal of Pharmaceutical Science and Research
www.wjpsronline.com
Review Article
ISSN: 2583-6579
SJIF Impact Factor: 5.111
Year - 2025
Volume: 4; Issue: 2
Page: 1161-1176

A REVIEW ON GASTRO RETENTIVE DRUG DELIVERY: STRATEGIES FOR PROLONGED GASTRIC RETENTION

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Article Received: 01 March 2025 | | Article Revised: 22 April 2025 | | Article Accepted: 13 may 2025

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DOI: https://doi.org/10.5281/zenodo.15497951

How to cite this Article: Shashikant D. Modekar, Sujit T. Karpe, Krishna R. Kudale, Abhishek B. Ghalke, Sanika S. Survase, Sanjyot S. Kasture and Vishwambhar A. Vhatkar (2025) A REVIEW ON GASTRO RETENTIVE DRUG DELIVERY: STRATEGIES FOR PROLONGED GASTRIC RETENTION. World Journal of Pharmaceutical Science and Research, 4(2), 1161-1176. https://doi.org/10.5281/zenodo.15497951

ABSTRACT

The potential of gastro retentive drug delivery systems (GRDDS) to improve patient compliance and therapeutic efficacy by extending stomach residence time and improving drug release kinetics has attracted much attention recently. This review offers a thorough summary of the most recent developments in GRDDS, emphasizing formulation tactics, design tenets, and assessment techniques. A detailed discussion of several strategies is given, emphasizing their modes of action and uses in targeted drug delivery, including floating, Mucoadhesive, expandable, and magnetic systems. Furthermore, new GRDDS with enhanced stability, controlled release profiles, and biocompatibility have been made possible by recent advancements in formulation technologies and materials science. The paper also discusses the difficulties that come with GRDDS, such as medication stability, physiological variability, and regulatory issues, and suggests possible solutions. Furthermore, the clinical applicability of GRDDS in the management of different gastrointestinal conditions and their potential use in targeted therapy and personalized medicine will be examined. The overall goal of this study is to offer insightful information on the state-of-the-art in GRDDS research at the moment and how it relates to the development of drug delivery technology.

KEYWORDS: Gastro retentive drug delivery systems (GRDDS); Bioadhesive; Mucoadhesive; floating drug delivery system.

INTRODUCTION

Oral administration is the most sensible and advised way to get any drug into the bloodstream. In order to obtain more therapeutic benefits, including patient compliance, compositional flexibility, and convenience of dose administration, the pharmaceutical industry has recently shown a greater interest in oral controlled release drug delivery. Drugs that are easily absorbed from the gastrointestinal tract (GIT) and have brief half-lives are quickly eliminated from the bloodstream.

To achieve the intended therapeutic effect, these drugs need to be dosed often. Oral sustained-controlled release formulations have been created in an attempt to overcome this limitation. These formulations maintain an effective concentration of the drug in the systemic circulation for a long time while releasing it gradually into the gastrointestinal tract (GIT). This type of pharmaceutical dispersion occurs after oral consumption.

When designing a site-specific oral controlled release dosage form, it is preferable for the drug administration to have a longer stomach residence duration. Drugs that are less soluble in high pH conditions become more soluble when the stomach is retained for a longer period of time. It also reduces medication waste. Furthermore, local action in the upper part of the small intestine, such as the treatment of peptic ulcers, may benefit from a longer gastric retention time (GRT) in the stomach.

Gastro retentive medicine delivery targets the upper gastrointestinal tract (GIT) for local or systemic effects by site-specific drug release by prolonging the stomach residence time. Using gastro retentive dosage forms, which can remain in the stomach region for prolonged periods of time, can significantly increase the gastric retention time (GRT) of drugs.[1]

Super porous hydrogel systems, magnetic systems, Mucoadhesive systems that cause bio-adhesion to the stomach mucosa, high density (sinking) systems that are retained in the stomach bottom, low density (floating) systems that cause buoyancy in gastric fluid, and unfoldable, extendable, or swellable systems that restrict the number of dosage forms that can be emptied through the stomach's pyloric sphincter are just a few of the gastro-retentive drug delivery techniques that have been developed in recent decades. To enable continuous absorption of the medication into the upper gastrointestinal (GI) tract, gastro retentive dosage forms (GRDFs) release their active ingredients in the stomach over a prolonged period of time.[2]

Why is GRDDS necessary? Some drugs that are absorbed through the gastrointestinal tract (usually have short half-lives) must be taken on a regular basis since they are quickly removed from the bloodstream. Innovative gastro-retentive drug delivery devices are being used to address this problem. They require fewer dosages because of their effective plasma drug concentration. By delivering the drug in a controlled and reliable manner, this method also has the benefit of eliminating variation in plasma drug concentrations.[3]

❖ **Stomach overview**

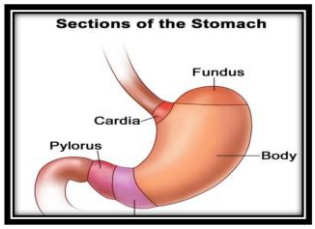


Figure 1: Parts of the stomach.

In the epigastric, umbilical, and left hypochondria areas of the abdomen, the stomach is a 'J' shaped expansion of the GI tract situated immediately inferior to the diaphragm. The duodenum, the first segment of the small intestine, is connected to the esophagus by the stomach.[4]

Cardia

The cardia encircles the stomach's upper entrance. The area of the stomach that surrounds the cardiac orifice, also known as the cardio esophageal junction (the entry of the esophagus into the stomach), is called the cardia.

Fundus

The expanded area to the left and above the heart opening is known as the fundus.

Body

The body the stomach's core is known as the body or corpus.

Pylorus

The pylorus is the area of the stomach where the duodenum joins it. The pyloric antrum, which joins the stomach's body, and the pyloric canal, which enters the duodenum, is its two components. When the stomach is empty, the mucosa is arranged in rugae, which are bigger folds. The pyloric sphincter is the sphincter that connects the pylorus to the duodenum of the small intestine. The stomach's convex lateral border on the right side is known as the larger curvature, while the concave medial border on the left side is known as the lesser curvature.[5]

The Stomach's Histology

There are four fundamental layers that make up the stomach wall. Mucous surface cells are a layer of simple columnar epithelial cells that cover the mucosa's surface. Additionally, epithelial cells descend into the lamina propria to create columns of secretory cells known as gastric glands and numerous small pathways known as gastric pits. The stomach lumen receives the gastric glands' secretions after first passing through the gastric pits. Three different kinds of exocrine gland cells—lumen mucus neck cells, chief cells, and parietal cells—are found in the glands and discharge their products into the stomach.[6]

Emptying the stomach

The GIT is continuously moving at all times. Food digestion involves two different motility patterns: the inter digestive (or fasting) mode and the digestive mode. An inter digestive sequence of electrical events those cycles through the stomach and small intestine every two to three hours is what defines the fasting state. This activity, which is frequently separated into four successive phases, is known as the migratory myoelectric complex (MMC) or inter digestive myoelectric circle.

Phase I: The 30- to 60-minute quiescent phase during which there are no contractions or secretions.

Phase II: The 20–40-minute interval of sporadic contractions and bile discharges.

Phase III: The brief, four to six-minute interval of strong, frequent contractions. Because they help move undigested food from the stomach to the small intestine, these are also known as "housekeeper waves."

Phase IV: The 0–5-minute Interval that separates Phase III from Phase I.[7]

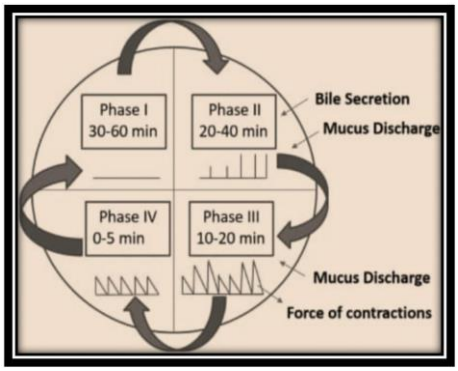


Figure 2: Phases of gastric motility & gastric emptying rate.

As seen in the figure, a full cycle of these four phases takes, on average, 90 to 120 minutes. If one wants to extend the gastrointestinal (GI) retention duration, GRDDs made to remain during the fasting state should be able to withstand the housekeeping action of phase III. GRDDs must have bioadhesive qualities that can adhere to the mucosal membrane and do so sufficiently robustly. Endure the shear forces generated in this phase.[8]

❖ **Advantages of GRDDS**

1. Increased bioavailability

The bioavailability of the former is significantly enhanced when riboflavin CR-GRDF is used in place of non-GRDF CR polymeric formulations. Numerous interconnected processes that affect drug absorption and transit through the gastrointestinal tract also affect the rate of medicine absorption.

2. Improved biotransformation in the first pass

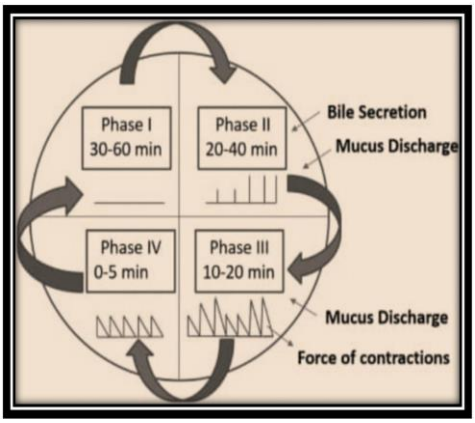


Figure 3: Phases of gastric motility & gastric emptying rate.

Presenting a molecule to metabolic enzymes (cytochrome P450, specifically CYP3A4) over an extended period of time can greatly increase pre-systemic metabolism, much of how active transporters with limited capacity can increase efficacy.

3. Reduced dosing frequency and sustained drug delivery

Flip-flop pharmacokinetics, which can be produced by slow and sustained input from CR-GRDF, can lead to a lower dose frequency for medications with brief biological half-lives. Better therapeutic results and patient compliance are the results of this trait.

4. Targeted treatment for upper gastrointestinal tract local conditions

Local treatment in the stomach may benefit from long-term drug delivery from GRDF to the stomach. The small intestine is also included. Because of absorption and dispersion, this mode of administration minimizes systemic levels while enabling the local achievement of therapeutic drug concentrations.

5. Decreased drug concentration fluctuations

When CR-GRDF is administered continuously, blood drug concentrations are narrower than when rapid-release dosage formulations are used. This reduces drug impact oscillations and avoids concentration-dependent side effects at high dosages. This factor is particularly crucial for medications with a small therapeutic index.[9]

6. Diminished bodily counter-activity

Drug reactions that disrupt normal physiological functions commonly cause the human body to become less responsive. As a result, there is less pharmacological activity. It has been shown that letting the medication enter the body gradually improves pharmacological efficiency and decreases counter activity.

7. Minimizing colonic side effects

The medication's exposure to the colon is decreased when it is kept in the GRDF in the stomach. Consequently, the adverse effects of the medication on the colon can be prevented. This pharmacodynamics feature serves as the foundation for the GRDF formulation of beta-lactam antibiotics, which are only absorbed from the small intestine, because their presence in the colon may result in microbial resistance.

8. Reduction of drug concentration variations

By activating different kinds of receptors at different dosages, it permits selective pharmacological effects.

9. Site-specific drug delivery

Using a floating dose form makes sense, especially for drugs with limited absorption sites in the upper small intestine. The medications controlled, progressive release into the stomach not only lowers its systemic exposure but also provides adequate local therapeutic levels. This reduces the negative effects the drug has on blood circulation. Additionally, the prolonged stomach availability offered by a site-directed delivery device may reduce the frequency of doses.[10-15]

❖ **Disadvantages of GRDDS**

- Not appropriate for medications with low acid solubility. For instance, phenytoin.
- Drugs that are unstable in acidic environments should not be used. Erythromycin, for instance.
- Medications with a delayed release that irritate the stomach or cause sores. For instance, NSAIDs and aspirin.
- Medications with selective colon absorption. Corticosteroids, for example.
- Medications that are as well absorbed by the GIT. For example, nifedipine and isosorbide dinitrate.
- Floating medication delivery devices need a high stomach fluid level in order to function properly.[16]

❖ **Factors affecting gastric retention time of the dosage form**

1. Density

The dosage form's density should be lower than the gastric contents' density (1.004g/ml).

2. Shape and size of dosage form

When creating indigestible single-unit solid dosage forms, the size and shape of the dosage forms are crucial. Non-floating dose forms can be big, medium, or small units, and their mean stomach residence periods vary widely depending on their size. Since a bigger dosage form would not be able to pass through the pyloric antrum and into the intestine as rapidly, the gastric retention time (GRT) will typically be longer for larger dosage forms. When compared to dosage forms with a diameter of 9.9 mm, those with a diameter greater than 7.5 mm exhibit a better stomach residence time. Devices with a ring or tetrahedron shape have a longer stomach residency period than those with other shapes.[17]

3. Fed or unfed state

Because stomach motility increases during fasting, there is a shorter gastric retention time.[18]

4. Caloric content

A meal heavy in fat and protein can raise GRT by 4–10 hours.[20]

5. Meal frequency

Because MMC occurs infrequently, feeding increases over 400 minutes when multiple meals are compared to a single meal.[21]

6. Gender

Regardless of height, weight, or body surface, the mean ambulatory GRT for males (3.4 hours) is lower than that of their age and race-matched female counterparts (4.6 hours).[22]

7. Age

Individuals over 70 have a noticeably longer GRT.[23]

8. The amount of GI fluid

The stomach has a resting capacity of 25 to 50 milliliters. Larger volumes result in speedier emptying. Body-temperature fluids exit the stomach more quickly than warmer or colder ones.[24]

❖ **Strategies for delaying drug transit through GIT.[25]**

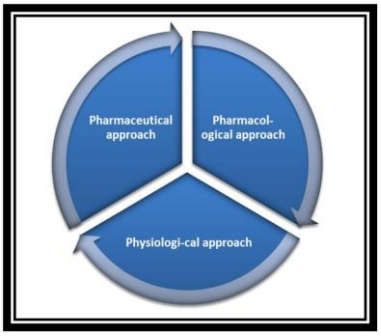
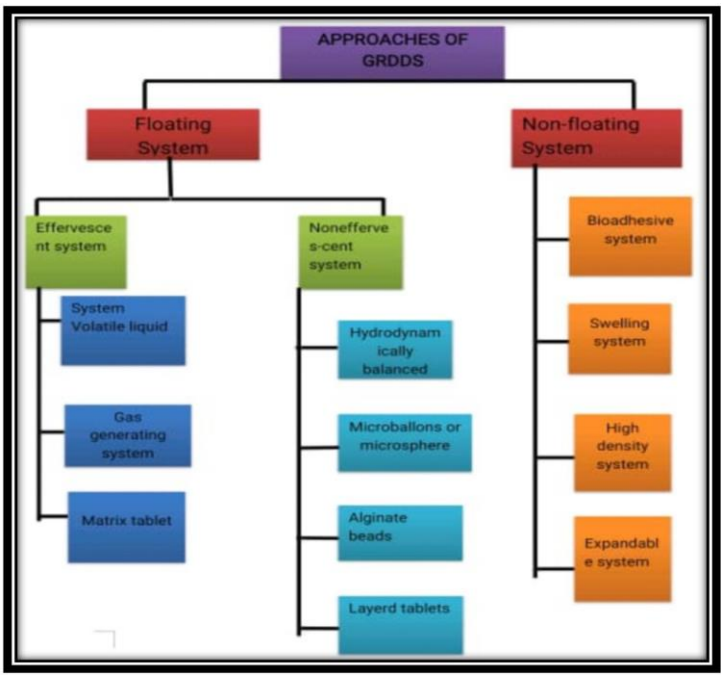


Figure 4: Strategies.

❖ **Approaches of GRDDS[26]**



- **Floating medication delivery device**

Floating Drug Delivery Systems (FDDS) are a type of controlled drug delivery system designed to improve the bioavailability and effectiveness of drugs by prolonging their gastric residence time. These systems remain buoyant on gastric fluids due to their low density, allowing them to stay in the stomach for extended periods and release the drug slowly.

- **Effervescent systems:** Use gas generation (e.g.: sodium bicarbonate with citric acid).
- **Non-effervescent systems:** Use swellable or bioadhesive polymers.[27]

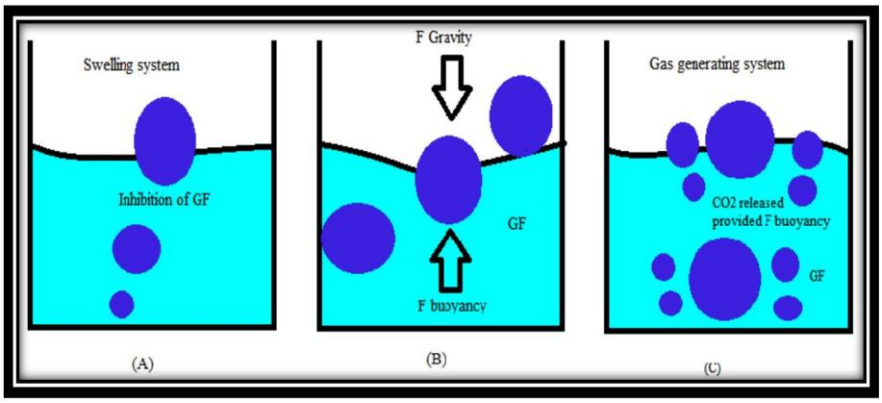


Figure 5.

- **Effervescent system**

An effervescent system in floating drug delivery relies on gas generation to achieve buoyancy. It contains components like sodium bicarbonate, citric acid, or tartaric acid, which react with gastric fluid to release carbon dioxide. The gas gets trapped in the dosage form, reducing its density and allowing it to float on gastric fluids.[28]

❖ **Types of floating drug delivery systems**

a. Volatile liquid systems.[29]

b. e.g.: Laivmudin

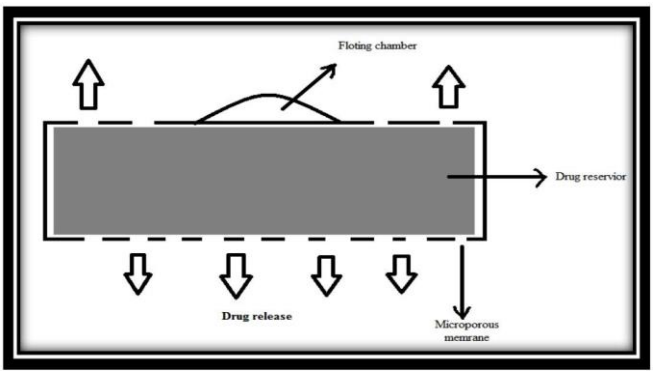


Figure 6.

b) Gas generating system [30]: e.g.: Ranitidine Hydrochloride

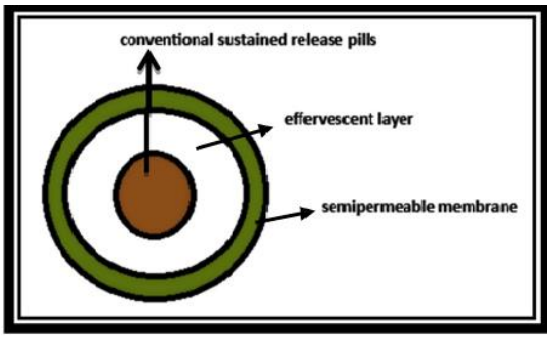


Figure 7: Gas-generating system.

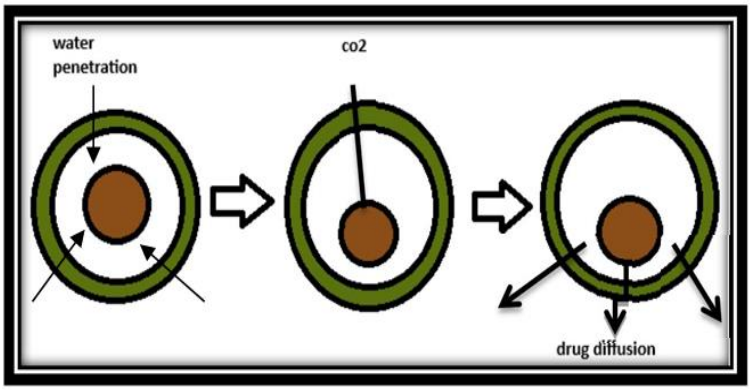


Figure 8: Drug release from effervescent (gas-generating) systems.

c) Matrix tablet systems[31]

e.g.: Stavudine

❖ **Non effervescent system**

A non-effervescent system is a type of floating drug delivery system that achieves gastric retention through the use of swellable or gel-forming hydrophilic polymers without relying on gas generation. These systems utilize the swelling and gelation properties of polymers to decrease the system's density, allowing it to float on gastric fluids.[32]

❖ **Types of non- effervescent system**

a) Microballons/ microsphere.[33]

- **e.g.:** Acyclovir

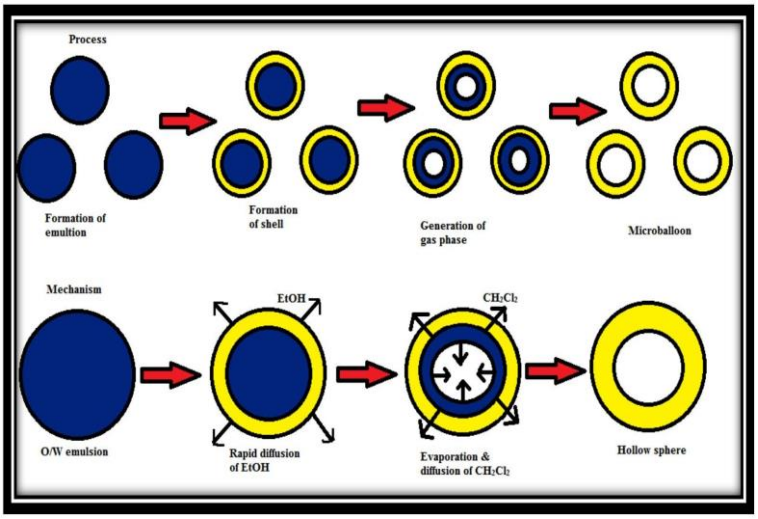


Figure 9: Microballons / Microsphere.

a) Alginate Beads: e.g.: Pantoprazole

b) Hydrodynamically balanced systems or colloidal gel barrier systems:

c) e.g.: ofloxacin

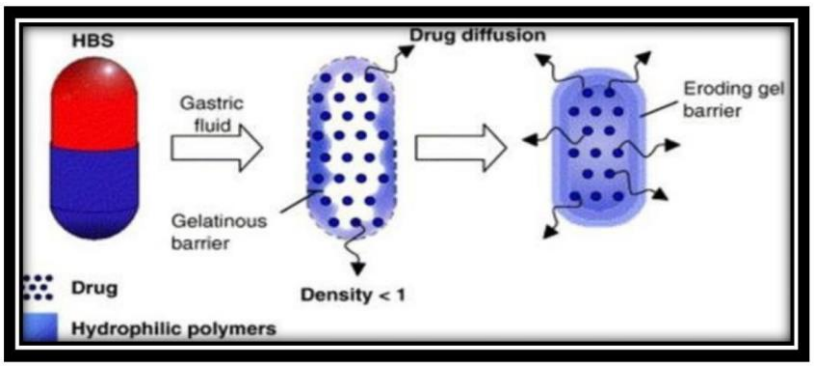


Figure 10: Hydrodynamically balanced systems.

d) Layered Tablets: E.g.: Misoprostol

❖ **Non floating drug delivery system**

1) High density systems

High-Density Systems are a type of non-floating drug delivery system designed to prolong the gastric residence time by utilizing a density higher than the gastric fluids (typically >1.5 g/cm³).

These systems sink to the bottom of the stomach and resist gastric emptying, ensuring sustained drug release.

- **Mechanism**

These systems remain at the bottom of the stomach due to their high density.

Gradual drug release occurs while the system is retained in the stomach.[34]

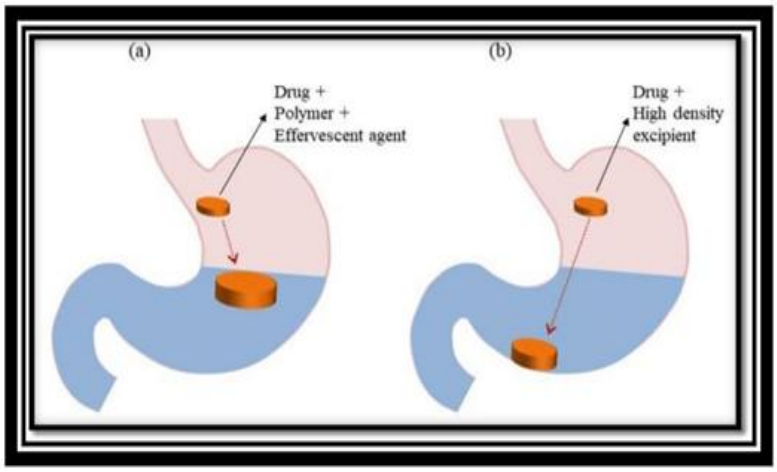


Figure 11: High Density (sinking) systems.

2) Bio-adhesive/Mucoadhesive system

A Bio-Adhesive System is a drug delivery system designed to prolong gastric residence time by adhering to the mucosal lining of the stomach or gastrointestinal (GI) tract. This adhesion is achieved using bio-adhesive polymers that interact with mucus or epithelial cells.

Contact stage

When the Mucoadhesive material makes contact with the mucosa, a tight wetting occurs between the mucous adhesion and mucosa. This wetting of the Muco-adhesives is made possible by the mucus present in the mucosa.

Stage of consolidation

Long-lasting mucous membrane adhesion is the outcome of the Mucoadhesive substance adhering to the mucous membrane through a variety of physical and chemical appealing elements. This phase is known as the merge or consolidation phase. Following these two stages, the mucous membrane adhesion process is finished.[35]

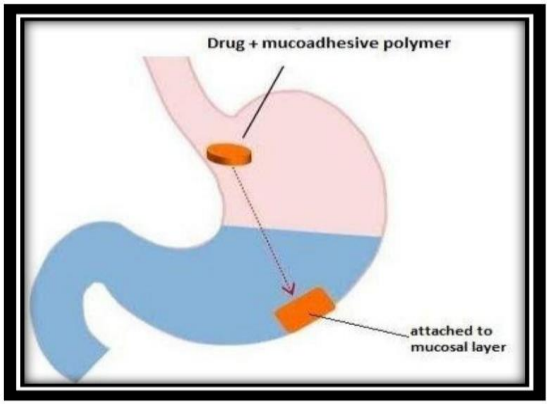


Figure 12: Mucoadhesive system.

3) Swelling/Expanding Systems

A Swelling or Expandable System is a drug delivery system designed to achieve prolonged gastric retention by increasing its size after ingestion. This prevents the system from passing through the pylorus, allowing it to remain in the stomach for an extended period.

4) Expandable Systems

Eg: Levodopa

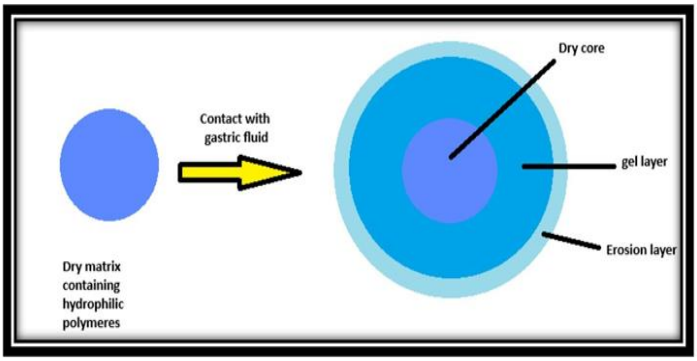


Figure 13: Swelling/Expanding Systems.

5. Systems of magnetism

The fundamental idea behind this technique for increasing the GRT is that a magnet is attached to the abdomen above the stomach location and a tiny internal magnet is incorporated in the dose form. Although the magnetic method seems to work, the requirement for precise external magnet setup may jeopardize patient compliance. The application of ultra-fine ferrite-containing bioadhesive granules in rabbits is a technical technique. They guided the granules to the esophagus for the first two minutes using an external magnet, and after two hours, almost all of them were still present.[37]

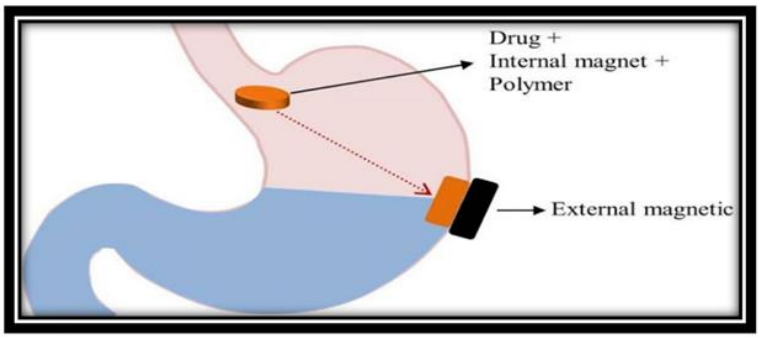


Figure 14: Systems of Magnetism.

Table 1: Commonly used drugs in the formulation of GRDDS.[38]

Sr.no.	Formulation	Drugs
1	Tablet	Amoxicillin trihydrate, Ampicillin, Captopril, Ciprofloxacin, Dilitiazem, Furosemide, Isosorbide mononitrate, Losartan, Metformin hydrochloride, P- Aminobenzoic acid (PABA), Sotalol, Verapamil HCl, Zidovudine
2	Capsule	Chlordiazepoxide HCl, Celiprolol HCI, Diazepam, Furosemide, L-Dopa and Benserazide, Misoprostal, Nicardipine
3	Films	Albendazole, P-Aminobenzoic acid (PABA), Prednisolone, Quinidine gluconate
4	Microspheres	Aspirin, Dipyridamole, Flurbiprofen, Griseofulvin, Ibuprofen, Nifedipine, Orlistat, Piroxicam, Rosiglitazone maleate Theophylline, Verapamil, amoxicillin
5	Powders	Several basic drugs-Riboflavin, Sotalol, Theophylline.
6	Granules	Cinnarizine, Diclofenac sodium, Diltiazem, Fluorouracil, Indomethacin, Prednisolone, Ranitidine HCl
7	Beads	Beta-cyclodextrin, Curcumin, Diltiazem HCl, Loratadine, Ranitidine HCl

❖ **Evaluation tests for GRDDS**

1. Floating Lag time

The lag time that floats the amount of time it takes for the dosage form to float on top of the dissolving media after being submerged in it is measured. These parameters may be measured as part of the dissolving test.[39]

2. Floating Time

Time spent floating Together with γ-scintigraphy and X-rays, an imaging technique is employed to evaluate dosage form placement and stomach retention throughout the GIT in vivo. In γ-scintigraphy, a small quantity of solid isotope is combined while being monitored by the dosage bureaucracy. Indirect use of a γ-digicam or scinti scanner is made possible when a system has a γ-emitting radionuclide. An evaluation medium for X-rays is barium sulfate. Finding a dose form that can be predicted and linked to the length of time the stomach empties and the passage of the dosage shape is made simpler by the GIT. Additionally, studies employing gastroscopy and ultrasonography may protect in vivo evaluation of GRDDS. Gastroscopy incorporates a number of oral endoscopic methods using a fiberoptic and video device. In order to assess GRDDS, ultrasonography is not automated. An in vivo plasma profile can also be obtained by doing the study in a suitable animal model.[40]

3. Swelling Studies

Studies on swelling for a hydrogel system that is very porous and extensible. To conduct the test, the swelling medium (0.01N HCl) is mixed with the weighted dose form. At certain intervals, the swollen samples' weight, diameter, and length are then measured.[41]

4. Rheology and viscosity

The viscosity of the polymer affects the consistency of the dosage form when it comes into contact with stomach fluid in systems that cause raft formation and Mucoadhesion; texture analyzers and Brookfield/Ostwald's viscometer are often used tools for this.

5. Moisture content, ion exchange capability, and particle size

A sieve shaker, laser diffraction, and a Coulter counter analyzer have all been used to measure the particle size of the ion-exchange resin system. The ion exchange capacity is determined by the functional group that is available for cross-linking. The moisture content can be tested using Karl Fischer.[42]

6. Strength of gel

For better mechanical integrity, high gel strength is desired.[43]

7. Studying the drug-excipient interaction

It can be done using FT-IR spectroscopy, differential scanning calorimetry, and high-performance liquid chromatography.[44]

8. Study of water uptake

At 37 OC, the dosage form is immersed in simulated gastric fluid, and periodic measurements are made of its thickness and diameter. The swollen tablets are weighed after the designated amount of time, and the formula WU= (Wt-Wo) X 100/Wo—where Wt and Wo represent the tablet's weight at time t and the beginning, respectively—is used to determine the percentage weight gain linked to water intake. The tablets are also evaluated for hardness, friability,

weight fluctuation, and other characteristics that are pertinent to conventional instant-release tablets. The tests listed below are essential for multiple unit dose form spheres, like microspheres, in addition to the ones already mentioned: Morphological and dimensional analysis: Scanning electron microscopy and optical microscopy are used to perform morphological and dimensional analysis. Microsphere yield as a percentage.

Entrapment efficiency: The drug is extracted with the proper method, and analysis is used to ascertain its concentration.[45]

9. Study of stability

The following tests are also essential for multiple unit dose forms in addition to the ones already mentioned. The ideal formulation for the produced floating micro balloons was selected based on buoyancy and the percentage of medication released. The selected mixture was stored for 90 days at three distinct temperatures: 27±2°C, 40±2°C, and 5- 8°C in the refrigerator, all in glass containers with borosilicate screw covers. The samples were routinely examined for drug entrapment, or drug content.[46]

10. In-vitro Dissolution Tests

GRDDS is used frequently, just like other common tablets, in in-vitro dissolving tests, which are frequently, conducted utilizing USP equipment with a paddle. The floating dose form, however, tends to float on the top when the vessel is large and the paddles are close to the bottom because of the decreased paddle force. Results could be erroneous and inconsistent if the floating dose form is not rotated. Several dissolution assembly transformations have produced reproducible results. They are shown in the figure that follows.

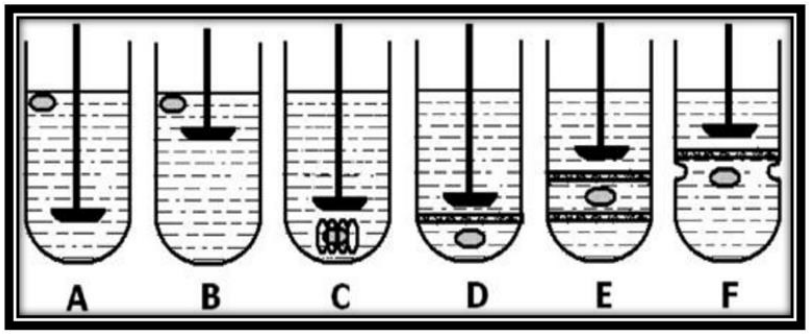


Figure 15: In-vitro dissolution tests.

Delivery of Drugs via Site For drugs like riboflavin that are exclusively absorbed from the stomach or the proximal portion of the small intestine, these systems are particularly helpful. The stomach absorbs furosemide the most, followed by the duodenum. It has been asserted that a monolithic floating dosage form was developed that increases absorption by having longer stomach residence duration. The floating pills' AUC was almost 1.8 times higher than that of conventional furosemide tablets. For local delivery of misoprostol, a synthetic counterpart of prostaglandin E1 used as a preventative measure against stomach ulcers brought on by NSAID consumption, a bilayer floating capsule was created.[47]

CONCLUSION

In conclusion, improved bioavailability and regulated drug administration are two possible benefits of gastric retention drug delivery systems. It has been demonstrated that the gastric retention drug delivery system may improve the

amount of medication that is retained in the stomach. As knowledge of how GIT physiology affects medication delivery grows, more and more drug delivery methods will be developed to maximize drug delivery by molecular techniques. Different regions have varying amounts of medication absorption.

The development of delivery technology will optimize the administration of molecules with a protracted first-pass metabolism, restricted bioavailability, and an absorption window, paving the way for the creation of more gastro-retentive drug delivery techniques. Because gastro-retentive drug delivery restricts absorption to the upper gastrointestinal tract and enables effective delivery, which maximizes absorption and improves absolute bioavailability, we concluded from our review of the literature that it offers several potential advantages for medications with low bioavailability. The patient benefits most from a gastro-retentive drug delivery system.

REFERENCES

1. Shinde shivram, tadwee Imran, shahi sadhana; Gastrortentive Drug Delivery System; International Journal of Pharmaceutical Research & Allied Sciences, 2011; 1(2):7-8.
2. Iannucelli V, Coppi G, Bernabei MT, Camerorni R. Air compartment multiple-unit system for prolonged gastric Residence. Part-I. Formulation study. Int J Pharm, 1998; 174: 47-54.
3. Garg R, Gupta GD. Progress in controlled Gastroretentive delivery systems. Trop. J Pharm Res, 2008; 7(3): 1055-1066.
4. Goole J, Vanderbist F, Aruighi K. Development and evaluation of new multiple-unit levodopa sustained-release f Loating dosage forms. Int J Pharm, 2007; 334: 35-41.
5. Shrma S, Pawar A. Low density multiparticulate system for pulsatile release of meloxicam. Int J Pharm, 2006; 313: 150-58.
6. Swetha S, Allena RT and Gowda DV: A comprehensive review on Gastroretentive drug delivery systems. International Journal of Pharmaceutical and Biomedical Research, 2012; 3: 1285-1293.
7. Pawar K. Vivek, Garg Garima, Awasthi Rajendra, Singodia Deepak, Kulkarni t. Giriraj; Gastrortentive dosage forms: A review with special emphasis on floating drug delivery systems; Drug Delivery, 2011; 18(2): 97-110, 98.
8. Goswami Anand, Jain Kumar Neetesh, Goyal Manoj ; An updated review on Gastroretentive drug delivery system; International Journal of Pharmaceutical Sciences Review and Research; December, 2020; 46-47.
9. Fagoonee S and Pellicano R. Helicobacter pylori: molecular basis for colonization and survival in gastric Environment and resistance to antibiotics. A short review, Infect Dis. (Lond), 2019; 51(6): 399-408.
10. Tomar Anu, Upadhyay Prakash, Gupta S K, Kumar Shobhit; An overview on Gastroretentive drug delivery system: Current approaches and advancements; Current Research in Pharmaceutical Sciences, 2019; 09(01): 12-16; 2.
11. Badoni A., Ojha A., Gnanarajan G., Kothiyal P., A review on Gastro retentive drug delivery system; The PharmaInnovation,2012; 36: 39.
12. Salunke Bhavana, Asija Rajesh, Goyal Kumar Anil, Kumar Jitendra; Gastroretentive drug delivery system: A Review ; International Journal of Allied Medical Science and Clinical Research, 2020; 301.
13. Dividevara Sai, Kumar Naveen K., Preethi K.; Gastro retentive drug delivery systems: A review; International Journal of Research in Pharmacy and Chemistry, 2020; 10(1): 98-100.
14. Krishna Murali Balijepalli, Patro Sekhar Chandra, Ramarao Taraka Ch., Uppala Kumar Parveen; Strategic Approaches & evaluation of gastro retentive drug delivery system- a review; Neuro Quantology, July 2022; 758-

759.

15. Jasssal Meenakshi, Nautiyal Ujjwal, Kundlas Jyotsana, Singh Devendra; A review: Gastroretentive drug dilvery System (GRDDS); Indian Journal of Pharmaceutical & Biological Research, 2015; 3(1): 83-92; 88, 89.
16. Patole Rutuja, Chaware Bharatee, Mohite Vishal, Redasani Vivek Kumar; A review for Gastro- retentive drug Delivery system; Asian Journal of Pharmaceutical Research & Development, 2023; 11(4): 79-94.
17. Hatwar R. Pooja, Channawar M.A.; Gastroretentive Mucoadhesive Drug Delivery System; World Journal of Pharmaceutical Research, 2020; 819-820.
18. Tripathi J, Thapa P, Maharjan R, Jeong SH. Current State and Future Perspectives on Gastroretentive Drug Delivery Systems. Pharmaceutics, 2019; 11: 193.
19. Sahu K, Alexander A, Thapa H, Banjare T, Agrawal P, Bhandarkar A, Bhatt A, Gupta S, Sahu H, Diwedi SD, P. Sahu P, Sahu SK, Yadav P, Dewangan D, Deepika, Badwaik HR, Sharma M, Tripathi DK, Ajazuddin. Formulation and Evaluation of gastro retentive sustained release tablets of ziprasidone hydrochloride. Research J. Pharm. And Tech, 2018; 11(5): 2080- 2085.
20. Schneider F, Koziolek M, Weitschies W. In vitro and In vivo test methods for the evaluation of Gastroretentive Dosage forms. Pharmaceutics, 2019; 11: 416-645.
21. Rojewska M, Bartkowiak A, Milanowski B, Prochaska K, Lulek J. Physicochemical and release studies of new Mucoadhesive fluconazole delivery systems. Colloids and Surfaces A, 2019; 566: 11–20.
22. Mehetre GD, Dubey A. Formulation-development and in-vitro-in vivo evaluation of Gastroretentive Floating Tablet incorporating clarithromycin. Journal of Drug Delivery & Therapeutics, 2019; 9(5): 67 81.
23. Silva JBDa, Ferreira SBDES, Freitas Ode, Bruschi ML. A critical review about methodologies for the analysis of Mucoadhesive properties of drug delivery systems. Drug Development and Industrial Pharmacy, 2017; 43(7): 1053-1070.
24. Katual MK, Gill NS, Singh G. Novel frontiers in buccal patches: a recent update. Journal of Applied Pharmaceutical Sciences and Research, 2018; 1(3): 8-19.
25. Siraj Shaikh, I. Khurshid Molvi, Nazim Sayyed; Various perspectives of Gastroretentive drug delivery system: A Review; American Journal of Advanced Drug Delivery, 2013; 443-451.
26. Fatema Kausar, Shahi S.R., Shaikh Tauqeer, Zaheer Zahid; Gastroretentive drug delivery system: An overview; Asian Pacific Journal of Health Sciences, 2016; 3(4): 131-144.
27. More Swapnil, Gavali Kaustubh, Doke Onkar, Kasgawade Prasad; Gastroretentive drug delivery system; Journal Of Drug Delivery and Therapeutics, 2018; 8(4): 24-35.
28. Jorgen F, Toftkjor H. Antacid composition.US Patent 50681095.14: 815.
29. Suryawanshi Amar, Khade Prashant, Bhosale Ashok; A review on: Gastroretentive drug delivery system; World Journal of Pharmacy and Pharmaceutical Sciences, 2021; 1668.
30. Stephen E. Harding; Biopolymer mucoadhesive a genetic engineering reviews; aprit, 1990; 16: 41-86.
31. El-said IA, Aboelwafa AA, Khalil RM and El Gazayerly ON. Baclofen novel Gastroretentive extended release gellan Gum super porous hydrogel hybrid system: Invitro- Invivo evaluation. Drug Deliv, 2016; 23: 101 112.
32. Neeraj Bhandari, Tanvi Bali, Tangun, Simran, Sumeena, Swati Choudhary; Gastro retentive drug delivery system:- A review; World Journal of Pharmacy and Therapeutical Sciences, 2017; 58-60.
33. Pant Shailaja, Badola Ashutosh, Kothiyal Preeti; A review on Gastroretentive Drug Delivery System; International Journal of Research and Development in Pharmacy and Life science, 2019; 5(4): 2178-2187

34. Kharvi Arpitha, N.S Ganesh, G. Lakshmikanth, Chandy Vineeth; A review on Gastro Retentive Drug Delivery System with a special focus on Floating Drug Delivery; American Journal of Pharmatech Research, 2019; 9(01).
35. Javaid Muhammad Umar, Zaman Muhammad, Shahid Safwa; A Comprehensive Discussion about Gastro Retentive Drug Delivery; International Journal of Pharmacy & Pharmaceutical Research, 2016, page no. 45.
36. K B Bineesha, Dharan S Shaiju, Jousha Abraham Sojan, Panicker T Jicky, James E Julie; Gastroretentive Raft Forming Drug Delivery: A Novel Expansion; International Journal of Pharmacy & Pharmaceutical Research,2019; 15(4): 200-212.
37. Sravya K, Kavitha K, Rupesh Kumar M, Jagdeesh Singh SD. Gastroretentive Drug Delivery Systems: A Review. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 2012; 3(3): 966-980.
38. Porwal A, Dwivedi H, Pathak K. Decades of research in drug targeting using Gastroretentive drug delivery systems for antihypertensive therapy. Brazilian J Pharm Sci, 2017; 53(3): 1–15.
39. Sharma AR and Khan A. Gastroretentive Drug Delivery System: An approach to enhance Gastric retention for prolonged drug release. Int J Pharm Sci Res, 2014; 5(4):1095-06.doi: 10.13040/IJPSR.0975-8232.5 (4).1095-06.
40. Goyal MK and Mehta SC "Preparation and evaluation of calcium silicate based floating microspheres of Amoxicillin" published in Journal Applied Pharmaceutical Sciences, 2011; 1(4): 137-141.
41. Gayakwad B.P. Natural polymers in the development of gastroretentive systems: A review. Nat. Volatiles & Essent. Oils, 2021; 8(5): 2895 2906s.
42. Kagan L. Hoffman A. Systems for region selective drug delivery in the gastrointestinal tract: Biopharmaceutical considerations. Expert Opin. Drug Deliv, 2008; 5(6): 681 - 692 10.1517/17425247.5.6.681 18532923.
43. Joshi P. A review on gastroretentive drug delivery system. Journal of Pharmaceutical Science and Bioscientific Research, 2012; 2(3): 123-128.
44. Ainurofi A. Daryati A. Murtadla F.A. Salimah F. Akbar N.M. Faizun R.A. The Use of Natural and Synthetic Polymers in the Formulation of Gastro retentive Drug Delivery System. Int. J. Drug Delivery Tech, 2023; 13(1): 434 441 10.25258/ijddt.13.1.69.
45. Singh B. Kim K.H. Floating drug delivery systems: an approach to oral controlled drug delivery via gastric retention. J. Control. Release, 2000; 63(3): 235-259 10.1016/S01683659(99)002047 10601721.
46. Ainurofi A. Daryati A. Murtadla F.A. Salimah F. Akbar N.M. Faizun R.A. The Use of Natural and Synthetic Polymers in the Formulation of Gastro retentive Drug Delivery System. Int. J. Drug Delivery Tech, 2023; 13(1): 434-441 10.25258/ijddt.13.1.69.
47. Ibrahim, M.; Naguib, Y.W.; Sarhan, H.A.; Abdelkader, H. Preformulation-Assisted Design and Characterization of Modified Release Gastroretentive Floating Extrudates Towards Improved Bioavailability and Minimized Side Effects of Baclofen. J. Pharm. Sci, 2021; 110: 1227–1239.