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A COMPREHENSIVE OVERVIEW OF FLOATING DRUG DELIVERY SYSTEM

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ABSTRACT
Floating Drug Delivery Systems (FDDS) are oral dosage forms designed to float on the gastric contents, prolonging their residence time in the stomach and facilitating sustained release of the active pharmaceutical ingredient. Conventional drug delivery systems often suffer from limitations such as frequent dosing and low bioavailability, particularly in relation to rapid gastric emptying. Floating drug delivery systems have garnered significant attention in recent decades as a viable solution to these drawbacks. An optimal floating system is designed to reside in the stomach for a prolonged period, releasing the active pharmaceutical ingredient in a sustained manner. By floating on gastric contents, these systems achieve extended pharmacological effects, ultimately enhancing drug bioavailability. This review aims to provide a comprehensive overview of floating tablets, advantages, disadvantages, classification, preparation methods, evaluation techniques, and applications.

KEYWORDS: FDDS, NDDS, sustained release, HBS.

INTRODUCTION

Floating drug delivery systems are oral dosage forms designed to float on stomach contents, prolonging gastric retention time and allowing for sustained drug release. These tablets are designed to have a lower density than gastric fluids, enabling them to float on the stomach contents without affecting gastric emptying. Floating tablets can be particularly beneficial for drugs that are absorbed primarily in the stomach or upper small intestine, drugs with narrow absorption windows, or drugs that degrade in the alkaline environment of the intestine.

The formulation of floating tablets involves the incorporation of gas-generating agents and suitable polymers to ensure buoyancy and controlled drug release. Effervescent agents (e.g., sodium bicarbonate + citric acid) that release CO_2 in the stomach are also being used. The performance of floating tablets can be affected by the volume of gastric fluid, presence of food, and patient posture. These tablets are not suitable for drugs that cause gastric irritation or those that are unstable in acidic environments. The primary reason for the preference of floating tablets is their ability to improve drug bioavailability, enhance patient compliance, and ensure a more controlled and sustained release. These benefits make floating tablets ideal for drugs requiring prolonged gastric residence time, improved solubility, or reduced dosing frequency.[1]

1. ADVANTAGES[1,2]

- Floating tablets increase the bioavailability for drugs which can be metabolized in upper GIT. e.g. Ferrous salts, furosemide.
- It is beneficial for drugs which are intended for local action in the stomach. e.g. Antacids.
- It provides improved drug absorption.
- As floating tablets are gastroretentive, they can reduce dose frequency and gastric emptying time.
- A floating tablet can minimize mucosal irritation which is caused by acidic drugs like aspirin.
- Ease of administration with better patient compliance in treating diseases like GERDs.
- It provides specific drug delivery and enhanced oral bioavailability.

- The drug is delivered to the site of action, thus minimizing the side effects.
- Drugs having a short half-life can be administered as floating tablets to get better therapeutic activity.
- It can minimize adverse exertion at the colon.

2. DISADVANTAGES[1,2]

- The drugs administered which are absorbed in GIT, undergoes first pass metabolism. e.g: nifedipine, propranolol.
- The administration of tablets just before going to bed is not feasible.
- The dosage should be administered with a minimum of a glass full of water to maintain a high amount of fluid in the stomach for buoyancy of medication.
- Drugs with poor solubility and stability problems with gastric fluids cannot be formulated as floating tablets.
- Some drugs cause mucosal irritations and lesions to gastric epithelium.
- It shows variability in gastric emptying time.

3. CLASSIFICATION[3]

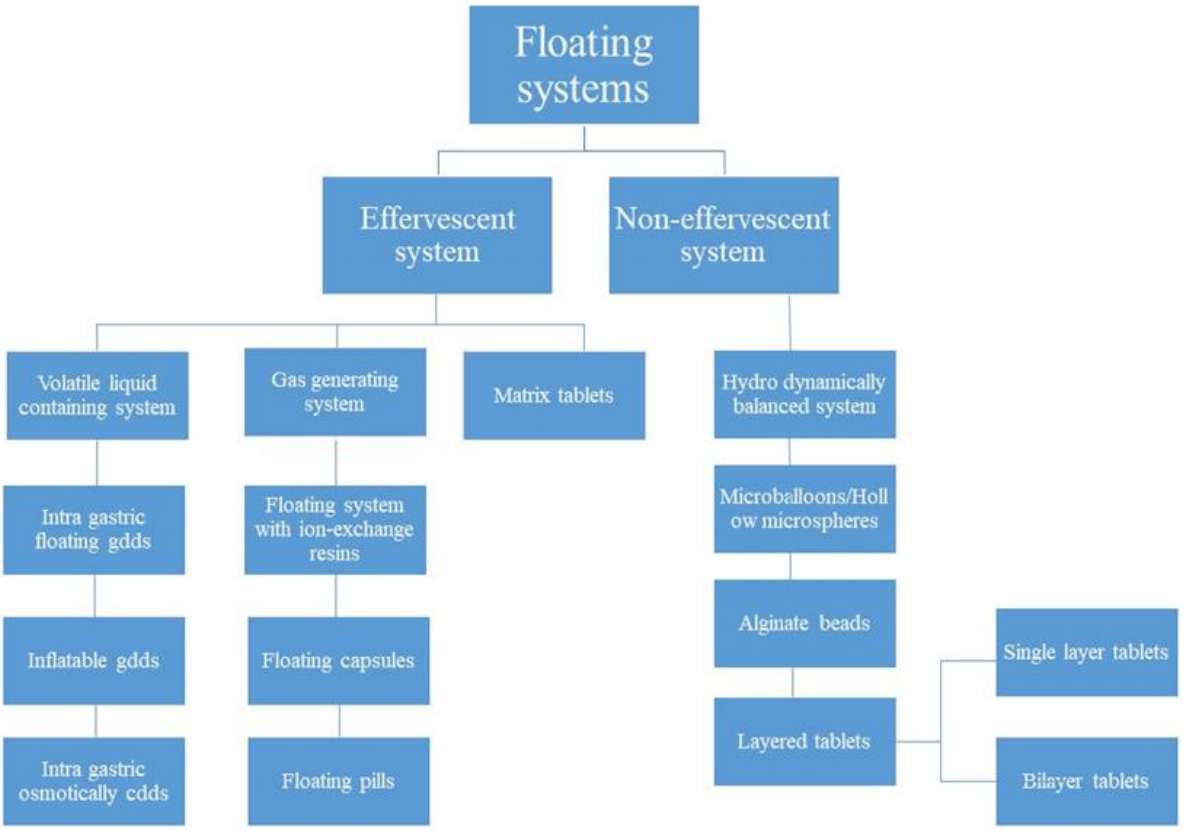

Figure 3.1: Classification of FDDS.

4. APPROACHES IN FLOATING TABLET[4,5]

4.1. EFFERVESCENT SYSTEM

In addition to producing CO_2, effervescent floating systems can reduce device density. These systems float in the stomach for a very long period. The sections that follow list a few FDDS that incorporate an effervescent mechanism within their architecture. In these systems, gas-producing substances such as citric and tartaric acids are used as internal effervescent layers to generate gas. This device demonstrated quick and prolonged buoyancy in addition to effectively regulating the release of medications with varying solubility.

Figure 4.1: Effervescent tablet.[6]

These are divided into

- Volatile liquid containing system

- Intra gastric floating gastrointestinal drug delivery system
- Inflatable gastrointestinal drug delivery system
- Intra gastric osmotically controlled drug delivery system

- Gas generating system
- Floating system with ion-exchange resins
- Floating capsules
- Floating pills

- Matrix tablets

4.1.1. Volatile liquid containing system

This system consists of two chambers separated by a pressure-responsive, impermeable, movable bladder. The first chamber contains the drug, while the second holds a volatile liquid such as ether or cyclopentane. At body temperature, the liquid vaporizes, inflating the chamber within the stomach and thereby prolonging gastric retention time. As the device remains inflated, the drug is continuously released.

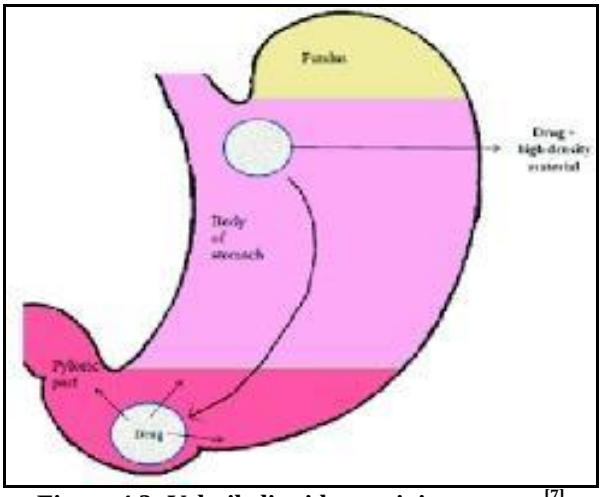

Figure 4.2: Volatile liquid containing system.[7]

4.1.1.1. Intra gastric floating gastrointestinal drug delivery system

This system contains a floatation chamber, which contains vacuum or an inert, harmless gas and a microporous compartment enclosing drug reservoir.

4.1.1.2. Inflatable gastrointestinal drug delivery system

These systems contain an inflatable chamber filled with liquid ether, which vaporizes at body temperature, causing inflation in the stomach. The drug reservoir either a drug impregnated polymer matrix or similar, is enclosed within this chamber. The drug reservoir either a drug-impregnated polymer matrix or similar, is enclosed within this chamber. The entire assembly is encapsulated in a gelatin capsule that dissolves upon reaching the stomach, releasing both the drug reservoir and the inflatable chamber. Once released, the chamber inflates automatically, allowing the drug reservoir to remain buoyant and retained in the gastrointestinal fluid for sustained drug release.

4.1.1.3. Intra gastric osmotically controlled drug delivery system

This system consists of an osmotically controlled drug delivery device enclosed within an inflatable floating capsule. Upon reaching the stomach, the capsule disintegrates, releasing the drug delivery system, which is made up of two main parts: a drug reservoir compartment and an osmotically active compartment.

4.1.2. Gas generating system

The primary mechanism of this system involves the generation of carbon dioxide gas through a reaction between Sodium bicarbonate, Citric acid, and Tartaric acid. This gas lowers the system's density, enabling it to float on gastric fluids. The released CO_2 becomes trapped within the jellified hydrocolloid layer, reducing the system's specific gravity and allowing it to remain buoyant on the chime. The tablet's buoyancy allows it to float on stomach contents, resulting in prolonged retention in the stomach and sustained release of the drug.

4.1.2.1. Floating system with ion-exchange resins

A floating drug delivery system using ion-exchange resin involves the complexation of the drug with a resin that can exchange ions in the gastrointestinal fluid. The drug-resin complex is then incorporated into a matrix or coated system that enables floatation by trapping air or releasing gas. Once in the stomach, the system floats on gastric fluids and slowly releases the drug through ion exchange, allowing for prolonged gastric residence and sustained drug release.

4.1.2.2. Floating capsules

Floating capsules are gastro retentive drug delivery systems designed to remain buoyant in the stomach for an extended period, enhancing drug absorption in the upper gastrointestinal tract. They typically contain a low-density core, gas-generating agents (like sodium bicarbonate), or swellable polymers that cause the capsule to float on gastric fluids. Once ingested, the gelatin capsule dissolves in the stomach, and the contents expand or generate gas, keeping the dosage form afloat while gradually releasing the drug for sustained therapeutic effect.

4.1.2.3. Floating pills

Floating pills are oral dosage forms designed to remain buoyant on gastric fluids, prolonging gastric residence time and enhancing drug absorption in the upper gastrointestinal tract. They are formulated using low-density materials, swellable polymers, or gas-generating agents (like sodium bicarbonate with citric acid) that create buoyancy. Once in the stomach, the pill swells or produces gas, allowing it to float and release the drug in a controlled or sustained manner over time.

4.1.3. Matrix tablets

This system can be formulated as a single-layer matrix tablet by incorporating bicarbonates into a hydrocolloid

gel-forming agent, or as a dual-layer matrix tablet with one layer containing the gas-generating matrix and the other containing the drug. A triple-layer matrix tablet is also possible, where the gas-generating matrix forms one layer, and the remaining two layers contain the drug.

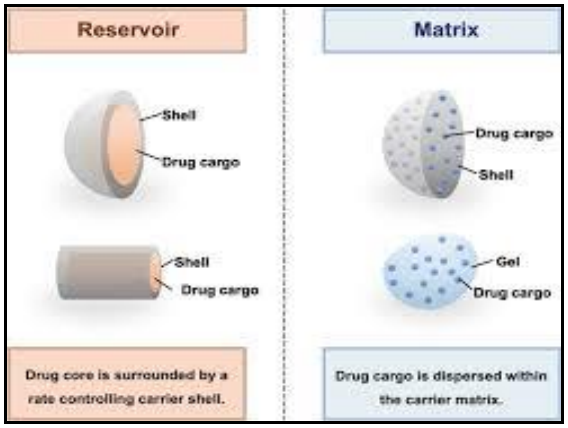

Figure 4.3: Examples of reservoir type and matrix type drug delivery.[8]

4.2. NON EFFERVESCENT SYSTEM

An-effervescent systems typically consist of a matrix-forming polymer such as polycarbonate, polystyrene, polymethacrylate, or polyacrylate combined with a highly swellable hydrocolloid, often a polysaccharide or a cellulosic compound. When exposed to gastric fluids, the hydrocolloid hydrates to form a low-density gel network that traps air, enabling the system to float on the stomach contents. Drug release is regulated by this gel layer: hydrophilic drugs are primarily released through diffusion, while hydrophobic drugs are released via erosion of the outer gel surface.

It is classified into

- HBS
- Micro balloons/Hollow microspheres
- Alginate beads
- Layered tablets
  - Single layer tablets
  - Bilayer tablets

4.2.1. Hydro dynamically balanced system

Hydrodynamically balanced systems (HBS) are single-unit dosage forms that utilize gel-forming hydrophilic polymers to achieve gastric retention. Hydroxypropyl methylcellulose (HPMC) is the most commonly used polymer, though others such as sodium carboxymethyl cellulose (NaCMC), carrageenan, hydroxyethyl cellulose (HEC), hydroxypropyl cellulose (HPC), and alginic acid are also employed. The drug-polymer mixture is typically encapsulated in a gelatin capsule, which quickly dissolves upon contact with gastric fluid, allowing the polymers to hydrate and form a floating gel matrix. The drug is mixed with one or more of these polymers and filled into a gelatin capsule. Upon ingestion, the capsule dissolves rapidly in gastric fluid. The hydrophilic polymers swell and form a gel that has a lower density than gastric fluid. This maintains buoyancy of the system, allowing it to float in the stomach and release the drug slowly over time. HBS enhances bioavailability for drugs absorbed mainly in the upper GI tract and reduces dosing frequency.

4.2.2. Microballoons/ Hollow microspheres

Microballoons or hollow microspheres containing drugs are typically prepared using emulsification-solvent diffusion or simple solvent evaporation methods, where factors like polymer type, plasticizer, and solvent quality influence their buoyancy and drug release characteristics. Commonly used polymers include cellulose acetate, Eudragit S, polycarbonate, low methoxy pectin, and calcium alginate. These microspheres usually exhibit a spherical, porous structure that allows them to float in simulated gastric fluid for over 12 hours. However, a major challenge in achieving high drug loading is the drug's solubility in the aqueous phase during microsphere formation.

4.2.3. Alginate beads

Alginate beads can be incorporated into floating tablets to enhance gastric retention by providing buoyancy. When embedded in a tablet matrix, they help the dosage form float on gastric fluids for extended periods, improving drug release and absorption in the stomach. The beads are formed by adding a sodium alginate solution into a calcium chloride solution, resulting in the precipitation of calcium alginate. After separating and drying the beads through air convection or freeze-drying, a porous structure is developed, enabling the beads to maintain buoyancy for over 12 hours.

4.2.4. Layered tablets

Layered tablets are multi-layered solid dosage forms composed of two or more distinct layers, each potentially containing different drugs or excipients, separated physically within the same tablet structure. They are designed for: Controlled or sequential drug release (e.g., immediate release + sustained release), Drug incompatibility management, by separating reactive ingredients into different layers, Improved patient compliance, by combining multiple therapies in one tablet.

Types Include

4.2.4.1. Single layer tablets - tablets with single layer.

4.2.4.2. Bilayer tablets – two layers with different release profiles or drugs.

4.2.4.3. Triple-layer tablets – three distinct layers for complex delivery strategies. They are manufactured using special tablet presses that can compress multiple layers sequentially.

Figure 4.4: Single layer tablet.[10]

Figure 4.5: Bilayer tablet.[9]

5. FORMULATION IN FLOATING TABLET[11,12]

5.1. ACTIVE PHARMACEUTICAL INGREDIENTS (APIs)

5.1.1. POTENTIAL CANDIDATES FOR FDDS

- Drugs acting locally in the stomach. E.g. Antacids.
- Drugs that are primarily absorbed in the stomach. E.g. Amoxicillin.
- Drugs that are poorly soluble at alkaline pH. E. g. Furosemide, Diazepam.
- Drugs with narrow absorption window. E. g. Cyclosporine, Levodopa, methotrexate.
- Drugs which are absorbed rapidly from the GI tract. E. g. Metronidazole, Tetracycline.
- Drugs that degrade in the colon. E. g. Ranitidine, Metformin.
- Drugs with less half life.

5.1.2. RATIONALE FOR DRUG SELECTION

The rationale for drug selection is very important. The selection of drugs should consider the solubility of the drug. The biopharmaceutical system (BCS) relies on solubility and drug permeability. For FDDS the drugs selected should be very soluble in GIT to get better bioavailability. The dissociation constant should be in the range of >2.5 for acidic drug so that the drug stays unionised at gastric pH. The partition co-efficient should be >1 for better lipophilicity. Drugs with shorter half-life should be selected for FDDS, preferably 2-6 hrs. The drug with high acid stability can be exclusively developed as FDDS.

5.2. POLYMERS USED IN FLOATING TABLETS[13]

5.2.1. NATURAL POLYMERS

5.2.1.1. Chitosan

It is a biodegradable, biocompatible polymer which forms a gel when contact with acidic pH which promotes buoyancy and sustained drug delivery. Used in floating microspheres and beads tablets.

5.2.1.2. Guar gum

It is a biodegradable gel forming natural polymer providing sustained drug release. Used in matrix floating tablets.

5.2.1.3. Xanthan gum

It is a biodegradable polymer which has the advantage of thickening and stabilizing properties and promoting floating and controlled drug release. It is used in combination with other polymers. Used in floating matrix tablet

5.2.1.4. Alginates

In contact with gastric fluids they form hydro gels that swell in the stomach in order to promote floating and controlled drug delivery. Used in floating alginate beads and raft systems.

5.2.1.5. Hydroxy propyl methyl cellulose (HPMC)

A widely used polymer for controlled drug delivery due to its gel forming capability.different grades are available in market like HPMC K4M, HPMC K15M, HPMC K100M. Used in floating matrix systems.

5.2.1.6. Methyl cellulose

Due to its high water immersion capacity it provides buoyancy and prolonged floating effect.

5.2.1.7. Ethyl cellulose

The polymer which is frequently used in combination with other polymers to achieve improved controlled drug release and better floatation.

5.2.2. SYNTHETIC POLYMERS

5.2.2.1. Eudragit (Methacrylic acid copolymers)

5.2.2.1.1. Eudragit RL and RS give controlled drug release and it helps to maintain buoyancy. They are primarily used for floating microspheres or microballoons.

5.2.2.1.2. Eudragit NE 30D used in coatings for floatable drugs.

5.2.2.2. Polyvinyl alcohol (PVA)

It is a biocompatible polymer having properties of forming stable hydrogels and aids in floatation. Used in microballoons and microspheres. By offering high lump capacity it provides prolonged floatation and controlled drug release. Also it is a water soluble polymer. Used for matrix and gas generating tablets.

5.2.2.3. Polylactic-co-glycolic acid (PLGA)

It is an excellent DDS due to its biocompatibility and biodegradability. Used in floating microspheres, microballoons, effervescent tablets.

5.3. EFFERVESCENT AGENTS

Effervescent tablets are key components in formulation of gas generating floating drug delivery systems, which are floating on gastric fluid to prolong gastric residence time by forming effervescent in contact with gastric acid. These agents react with gastric acid to produce carbon dioxide gas which is then trapped in the polymer matrix of the tablet. This causes reduction in density and allows the tablet to float.

The effervescent agents are commonly used in pairs as acid with base for controlled gas generating reaction. Commonly used effervescent agents are citric acid, tartaric acid, fumaric acid and malic acid as acid components as well as sodium bicarbonates, calcium carbonate, potassium bicarbonate as alkaline components.[14]

5.4. LOW DENSITY EXCIPIENTS

Low density excipients play an important role in the design of FDDS as they help to float the tablet by reduction of overall density. One of the widely used strategies involves use of hollow microspheres or microballoons. Low density foam powders like polypropylene are also used in matrix tablets.

5.5. BINDERS

Binders are a vital ingredient in a tablet formulation to ensure mechanical strength and integrity. This is important for floating tablets as they must withstand gastric agitation or peristalsis and maintenance of buoyancy for prolonged time. They control erosion and swelling of tablets in GIT. They ensure uniform distribution of gas generating or low density agents. Commonly used binders in FDDS are hydroxypropyl methyl cellulose (HPMC), polyvinylpyrrolidone(PVP K30), starch paste, gelatin, acacia, methyl cellulose. Among these the HPMC is a commonly used binder even though it is a swellable matrix polymer.

5.6. LUBRICANTS

In FDDS magnesium stearate, talc, sodium stearyl fumarate, hydrogenated vegetable oil are used as lubricants. According to Indian pharmacopeia, lubricants are excipients added in tablets formulation in small quantities to reduce friction between tablet granules and the machinery surfaces during compression process, thereby ensuring smooth processing and ejection from dies. They used to prevent the sticking of tablets into punches and walls of dies. It ensures smooth tablet ejection and improves processing flow. Lubricant provides elegance to tablets, smooth surface and uniformity to final dosage forms.

5.7. MISCELLANEOUS

Other pharmaceutically accepted excipients like preservatives and stabilizers are incorporated as requirements.

6. METHOD OF PREPARATION

Floating tablets are typically prepared using three basic compression methods: direct compression, dry granulation, and wet granulation. The choice of compression method depends on the specific requirements of the active ingredient and the desired tablet properties. Each method has its advantages and disadvantages, and manufacturers must carefully evaluate these factors to determine the most suitable approach for their product. By selecting the appropriate compression method, manufacturers can produce floating tablets with optimal characteristics, ensuring the delivery of high-quality products that meet regulatory standards and patient needs. Ultimately, the goal of tablet production is to create a product that is safe, effective, and reliable, and the choice of compression method plays a critical role in achieving this goal.[15,17]

6.1. Direct compression

It involves compressing tablets directly from powdered materials without altering their physical nature. This technique is suitable for crystalline substances with good compressibility and flow properties, such as ammonium chloride, sodium chloride, and potassium salts. In direct compression, a tablet machine compresses the powdered material under high pressure to form a tablet. This method is advantageous due to its simplicity and efficiency, allowing for faster production times and reduced costs.

6.2. Dry granulation

The method is defined as the formation of granules by slugging, particularly useful when tablet ingredients are sensitive to moisture or unable to withstand elevated temperatures during drying. This method is especially suitable for active ingredients that are sensitive to solvents, moisture, or heat. Dry granulation offers a shorter and more cost-effective manufacturing process compared to wet granulation, making it an attractive option for certain formulations. By avoiding the use of moisture and heat, dry granulation helps preserve the stability and potency of sensitive ingredients, ensuring the production of high-quality tablets.

In contrast, wet granulation involves mixing the active ingredient, diluents, and disintegrants in a rapid mixer granulator, followed by drying and granule formation. The wet granulation process requires careful control of drying conditions, typically using tray dryers or fluidized bed dryers. After drying, the granules are reduced in size and mixed with lubricants or glidants to promote flow before being compressed into tablets. While wet granulation is a widely used method, it may not be suitable for all formulations, particularly those containing moisture-sensitive ingredients.

7. EVALUATION OF FLOATING TABLET

Evaluation of floating tablets is done to ensure the quality, safety and efficacy of a floating tablet the evaluation parameters like floating lag time, duration of floating, total floating time, dissolution etc should be analysed. This examination will help to confirm that the tablets buoyant in the gastric fluid thus provide optimal drug release and absorption.[18,19]

EVALUATION PARAMETERS

7.1. Bulk density

Bulk density is defined as the ratio of powder to bulk volume. Particle size distribution, shape and cohesiveness can affect bulk density.An initial bulk volume is made by adding the powder into a graduated

measuring cylinder. The powder should be accurately weighed. The powder is added to the cylinder through a funnel and volume is measured. That measured volume is considered as the initial volume. It is expressed in gm/ml.
Bulk density=M/Vo
Where, M= mass of the Powder. Vo= bulk volume of the Powder.

7.2. Tap`ped density
Tapped density is the density of powder or granules after it has been tapped to settle the particles. The 100ml measuring cylinder is filled with 10gm of powder. The cylinder was tapped for 100 times by allowing the particles to settle. The tapped volume was recorded. It is expressed in gm/ml. The tapped density was calculated using the equation.
Tapped density = M/Vt
Where, M= mass of the Powder. Vt= final tapping volume of the Powder.

7.3. Angle of repose
Angle of repose is the maximum angle possible between the surface of the pile of the powder and the horizontal plane. Angle of repose indicates the flowability and cohesiveness of the powder. Fixed funnel method is used to determine angle of repose. A funnel was fixed with its tip at a given height 'h, above a flat horizontal surface to which a graph paper was placed. Powder was carefully poured through a funnel till the apex of the conical pile just touches the tip of the funnel. The angle of repose was then calculated using following equation:
Angle of repose (Ø) = tan1(h/r)

Interpretation of Angle of Repose values
- 0°-30°: Excellent flowability
- 30°-45°: Good flowability
- 45°-55°: Fair flowability
- 55°-65°: Poor flowability
- > 65°: Very poor flowability

7.4. Hausner's ratio
Hausner's ratio predicts flowability of the powder. It is represented by
Hausner's ratio= tapped density/bulk density.

7.5. Weight Variation test (U.S.P.)
Weight variation test is important to ensure uniformity. Take 20 tablets and weigh them individually. Average weight is calculated and the individual tablet weight to the average is compared. The tablet passed the U.S.P. test if no more than 2 tablets are outside the percentage limit and if no tablet differs by more than 2 times the percentage limit.

7.6. Hardness
Tablet hardness and strength are essential to see that the tablet can withstand the shock and stress during manufacturing, packing and transportation, and while handled by the patient. To test the hardness of the tablet Monsanto tester, Strong-cobb tester, the Pfizer tester, the Erweka tester, the Schleuniger testers are used.

7.7. Size and shape
The thickness of the tablet can be measured by micrometer or by another device. Tablet thickness should be controlled within ±5% variation of standard value.

7.8. Floating lag time and total floating time
The floating lag time can be defined as the time taken to emerge on the surface of the dissolution medium, and the time the tablet constantly floats on the surface of the medium is known as Total floating time. These were measured visually in dissolution apparatus type II containing100 mL 0.1 N HCl with a paddle rotated at50 rpm (pH 1.2) at 37 ± 0.5 °C.

7.9. Dissolution Study
In vitro drug release of the formulation was carried out using USP dissolution apparatus type II paddle type under sink condition with rotating speed of 50 rpm and at temperature of 37 ± 0.5 °C. 900ml 0.1NHCl can be used as a dissolution medium. The samples were withdrawn at predetermined time intervals for a period of 6hours and replaced with the fresh medium, suitably diluted and were analyzed using UV/Visible spectrophotometer.

7.10. Disintegration Test (U.S.P.)
The U.S.P. device to test disintegration uses 6 glass tubes that are 3 inches long; open at the top and 10 mesh screens at the bottom end. To test for disintegration time, one tablet is placed in each tube and the basket rack is positioned in a 1-L beaker of water, simulated gastric fluid or simulated intestinal fluid at 37 ± 2 0 C such that the tablet remain 2.5 cm below the surface of liquid on their upward movement and not closer than 2.5 cm from the bottom of the beaker in their downward movement Move the basket containing the tablets up and down through a distance of 5-6 cm at a frequency of 28 to 32 cycles per minute. Floating of the tablets can be prevented by placing perforated plastic discs on each tablet. According to the test the tablet must disintegrate and all particles must pass through the 10-mesh screen in the time specified. If any residue remains, it must have a soft mass. Disintegration time: Uncoated tablet: 5-30 minutes coated tablet: 1-2 hours.

8. APPLICATION[21,22]
8.1. Sustained Drug Delivery: This system allows for controlled drug release over time, prolonging gastric residence. For example, sustained-release floating capsules of nicardipine have shown effective *in vivo* performance.

8.2. Site-Specific Delivery: It is ideal for drugs absorbed in the stomach or upper intestine, such as diuretics and vitamin B2, significantly enhancing bioavailability. Site-specific drug delivery systems provide controlled, gradual drug delivery to the stomach, which provides appropriate local

therapeutic rates and reduces the systemic exposure of the drug. The dosing frequency can be decreased by extended gastric availability from a site-driven drug delivery system, as seen in examples like Furosemide and Riboflavin.

8.3. Absorption Enhancement: This system improves bioavailability for drugs with site-specific absorption in the upper GI tract. For instance, floating formulations have shown superior absorption compared to conventional forms. Floating drug delivery systems have various uses for medications that struggle with low bioavailability due to the limited absorption area in the upper gastrointestinal tract. By keeping the dosage form at the absorption site, these systems improve bioavailability.

8.4. Constant Blood Levels: It ensures steady drug release, maintaining consistent blood levels, with easy administration and better patient compliance.

8.5. Minimized adverse reaction at the colon: Minimized adverse reaction at the colon is achieved as retention of the drug in the stomach in HBS minimizes the amount of drug entering the colon, thus avoiding unwanted drug activity in the colon region.

8.6. Enhanced bioavailability: Enhanced bioavailability is achieved as the bioavailability of riboflavin CR-GRDF is substantially increased compared with the administration of non-GRDF CR polymeric formulations. Sustained delivery of drugs is possible as oral CR formulations experienced problems in the GIT like gastric residence time, but HBS systems that can stay in the stomach for a prolonged period of time and having a bulk density of less than 1 can float on the gastric contents and overcome these problems.

8.7. Reduced drug concentration fluctuation: Reduced drug concentration fluctuation is also possible as continuous input of **the** drug following CR-GRDF administration creates concentrations of the blood drug within a narrower range compared with types of immediate release dosage forms.

9. CONCLUSION

Floating drug delivery systems (FDDS) have emerged as one of the most effective gastro-retentive approaches for improving the bioavailability and therapeutic performance of drugs with narrow absorption windows or site-specific activity in the upper gastrointestinal tract. Over the past decades, extensive research has focused on optimizing formulation parameters, such as polymer composition, effervescent agents, and tablet geometry, to achieve desirable buoyancy, controlled release, and prolonged gastric residence time. This review highlights that hydrophilic and hydrophobic polymers, including HPMC, carbopol, and ethylcellulose, play a critical role in modulating drug release and maintaining matrix integrity. The combination of swelling polymers and gas-generating systems remains the most widely investigated strategy for achieving effective floatation and sustained drug delivery. Moreover, advancements in analytical techniques have facilitated more accurate in vitro and in vivo evaluations of these dosage forms. Despite these developments, challenges such as variable gastric emptying, physiological differences among patients, and scale-up limitations continue to affect the predictability and reproducibility of FDDS. Current research is increasingly focused on integrating novel excipients, nanotechnology-based carriers, and computational modeling to overcome these limitations and to establish a stronger in vitro–in vivo correlation. In conclusion, floating tablets represent a promising and evolving platform in oral controlled drug delivery. Their continued development, supported by innovative formulation technologies and deeper biopharmaceutical understanding, is expected to expand their clinical applicability and therapeutic reliability. Future work should emphasize patient-specific design, advanced polymer systems, and translational studies to facilitate successful commercialization of these gastro-retentive systems.

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