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REVIEW ARTICLE

A Comprehensive Review on The Floating Drug Delivery System

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ABSTRACT

The Floating Drug Delivery System is intended to examine buoyancy principles in order to achieve stomach preservation. The activities of the gastrointestinal tract must be known when investigating how medication is in the air. Floating tablets, both effervescent and non-effervescent, are manufactured using a variety of processes based on buoyant properties and concepts used in the manufacture of FDDS. Drugs that are unstable in the lower intestine environment, have a narrow absorption window in the upper gastrointestinal system, are low-soluble at higher pH levels, and are active locally can all be delivered using FDDS. The main objective of the present review is to compile the most recent research, with a special focus on benefits and downsides related to action mechanisms, preparation methods, and classification. Comprehensively covered are the latest advancements in FDDS, the physiological and formulation aspects affecting stomach retention, design approaches for floating systems incorporating one or more units, and the characteristics of their formulation and classification.

Keywords: Floating drug delivery system, Buoyancy, Gastric retention. CRDDS.

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INTRODUCTION

A pharmaceutical formulation, referred to as a floating drug delivery system (FDDS), extends the residence duration of the dose form within the gastrointestinal tract, thereby augmenting drug absorption, bioavailability, and therapeutic efficacy [1]. This innovative approach is gaining popularity as a solution to the challenges associated with conventional drug delivery methods. For medications characterized by poor solubility and enhanced absorption in the proximal part of the gastrointestinal system, the prolonged gastric retention offered by FDDS proves advantageous [2]. This leads to heightened patient compliance, reduced dosage frequency, and improved bioavailability and therapeutic effectiveness. Moreover, FDDS, by gradually introducing certain drugs into the body, has the potential to mitigate their adverse effects [3]. The controlled release mechanism of FDDS contributes to maintaining optimal medication levels in the bloodstream, resulting in a more reliable and efficient course of therapy [4]. This can improve patient compliance and overall treatment outcomes. This can improve patient compliance and overall treatment outcomes, ultimately leading to better health outcomes for patients.

A floating drug delivery system (FDDS) is also known as a hydro dynamically balanced system (HBS). The drug carriers in FDDS float in gastric fluid, which keeps drugs from exiting the stomach too soon [5]. By prolonging the release time, it successfully increases the bioavailability of drugs. Additionally, there is less variation in the blood concentrations of medications [2]. FDDS may be used to treat duodenal and

stomach issues. Gastric juice and chymus must have a higher density than FDDS carriers. Medications that float and release gradually, as opposed to convectional drug delivery systems, allow for more effective antibiotic penetration through the gastric mucus layer [6]. This enables FDDS to suppress or completely eliminate Helicobacter pylori in the stomach [7]. Not many FDDS float for two to eight hours. Controlled-release drug delivery systems (CRDDS) are critical for maintaining appropriate drug concentrations, boosting short-half-life drug action, avoiding side effects, reducing dosage frequency, optimizing therapy, and improving patient compliance. In addition, FDDS can improve the bioavailability of low-bioavailability and poorly soluble drugs in the gastrointestinal tract. Furthermore, controlled-release drug delivery systems provide the benefit of sustained drug release, which allows for a more consistent and lasting therapeutic effect. This is especially useful for drugs that require frequent doses or have a limited therapeutic window. Furthermore, FDDS can protect medications against degradation in the harsh acidic environment of the stomach, ensuring that they reach their target location of action in the body [8].

PHYSIOLOGY OF STOMACH

The purpose of floating medication delivery systems is to provide regulated and prolonged release of medication under specific gastrointestinal circumstances. These parameters include buoyancy, density, pH, motility, and stomach emptying time. The effectiveness of the devices is significantly impacted by these parameters [9]. The floating medication delivery devices can release the drug at the desired pace and location throughout the gastrointestinal tract by making sure they are made to respond to these particular stomach circumstances. Furthermore, minimizing any potential adverse effects or variability in drug absorption can be achieved by comprehending and managing these factors, which will improve patient compliance and treatment outcomes overall [7].

Stomach Anatomy & Physiology: -

The digestive organ responsible for food breakdown and nutrient absorption is the stomach; situated in the upper abdomen.[9] It comprises four distinct sections: the fundus, cardia, body, and antrum. Within the stomach's epithelial lining, four primary secretory cell types contribute to its functionality and structure when empty. These cells include mucous cells, chief cells, parietal cells, and G cells. Mucous cells specialize in secreting mucus, a protective substance that safeguards the stomach lining [10]. Chief cells, on the other hand, are responsible for the production of enzymes crucial for the digestion process. Parietal cells play a key role by secreting hydrochloric acid, contributing to the breakdown of ingested food particles [11]. Lastly, G cells release hormones that intricately regulate various aspects of stomach activity, orchestrating a finely tuned digestive process within the gastrointestinal system [12].

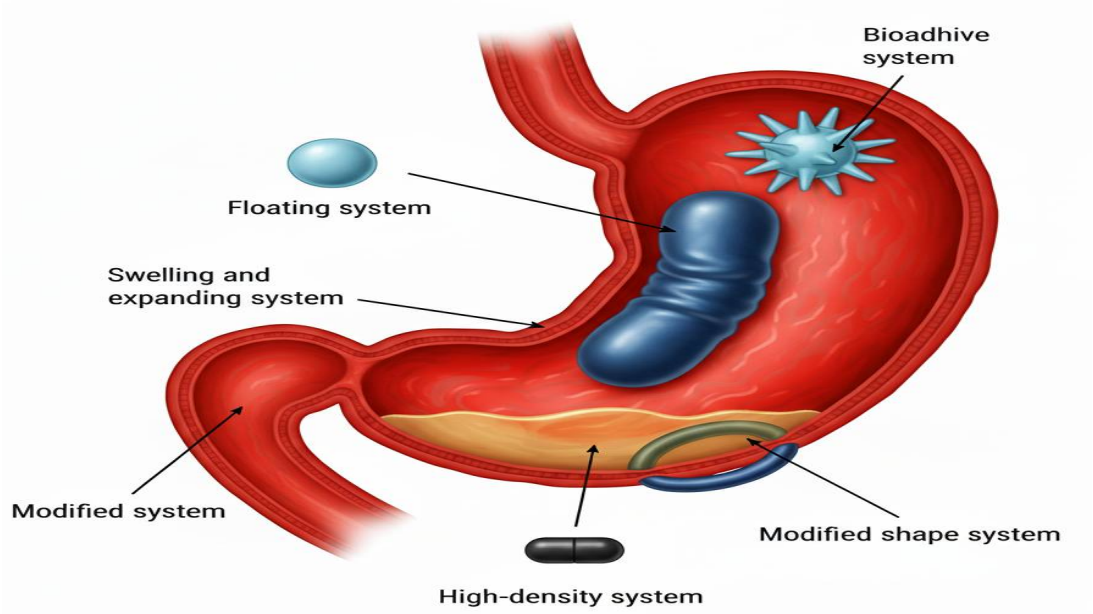

Fig. No. 01; Anatomy of Stomach

Maintaining gut health, avoiding bacterial overgrowth, and promoting the flow of food through the digestive tract all depend on the migrating myoelectric complex. The synchronized contractions and relaxations that occur during the MMC aid in the gastrointestinal system's ability to eliminate indigestible substances and avoid stasis [13]. The migrating myoelectric complex (MMC), an ordered, cyclic sequence of contractions in the stomach and small intestine, occurs during a fast. It is separated into four phases,

each of which is essential to the food's journey through the digestive system [14]. Stomach emptying occurs during both fasting and eating; however, the pattern of emptying differs significantly between the two.[15] During the inter-digestive sequence, a cycle of electrical events takes place in the stomach and small intestine every 90 to 120 minutes during fasting. The four phases of the MMC are as follows:

Table No. 01: Migrating Myoelectric Complex Phases

Sr. No.	Phase	Description	Duration	Key Features
1	Phase I	**Passive Phase;** A period characterized by relative inactivity, lasting 45 to 60 minutes post-meal or during fasting.	45 to 60 minutes	Low contractile activity in the stomach and small intestine.
2	Phase II	**Irregular Contractions**; Features increased and irregular contractions, lasting 5 to 15 minutes.	5 to 15 minutes	Associated with the initiation of MMC's cleaning and sweeping functions for the removal of undigested material.
3	Phase III	**Regular Contractions;** Represents the most vigorous phase of MMC, featuring regular, rhythmic contractions.	5 to 15 minutes	Utilizes strong contractions to propel remaining stomach contents into the small intestine; occurs 90 to 120 minutes apart.
4	Phase IV	**Shift Phase;** Marks the transition from Phase III to Phase I, taking about 15 to 30 minutes.	15 to 30 minutes	Denotes reduced contractile activity, preparing the digestive tract for the next MMC cycle.

a. Gastric Emptying Time: -The stomach's emptying time is the length of time it takes for the contents of the stomach to flow into the small intestine. During a fast, stomach emptying takes about two to four hours, but this might vary based on the meal's composition, the presence of lipids, and other physicochemical properties of the food taken [16].

b. **Density and Buoyancy**: - Low-density materials are used to make floating drug delivery systems, which enable them to float in stomach liquid [17]. These systems frequently use polymers or other materials to lower their total density and maintain their buoyancy [18].

c. Swelling and Gel Formation: - When certain polymers employed in floating systems come into contact with stomach secretions, they swell and form a gel-like structure. This expansion contributes to buoyancy maintenance and prevents the stomach from passing through the pyloric sphincter and entering the small intestine [19-20].

d. Gastric Motility: - Gastrointestinal motility, or the movement of the stomach walls, can alter the behaviour of the floating drug delivery system. Strong contractions and peristaltic motions can have an effect on the system's floating properties [21, 22].

e. Gas Generation: - Carbonates and bicarbonates, for instance, are gas-generating agents that form carbon dioxide when they come into contact with gastric acid. The gas produced enhances buoyancy and keeps the drug delivery device suspended [23].

f. pH of Gastric Fluid: - pH 1.5–3.5 is the acidic range of the stomach. Certain floating systems have a pH fluctuation response built into their design. pH-sensitive polymers may be used to initiate the release of the medication when the system comes into contact with the stomach's acidic environment [24].

g. Interaction with Food: - Food might impact the floating behaviour of the drug delivery system as well as the time it takes for the stomach to empty. Floating systems must be designed to stay floating regardless of the type of food consumed [6].

MECHANISM OF FLOATING DRUG DELIVERY SYSTEM

The FDDS has a lower bulk density than gastric fluid; it floats in the stomach without slowing down the pace at which the stomach empties. Slow and ideal drug release necessitates a minimum floating force (F). A novel apparatus maximizes durability and stability by computing floating-force kinetics. This technology guarantees drug release at the ideal rate and helps prevent unpredictable fluctuations in intragastric buoyancy performance. The new device calculates the optimal floating force by measuring a number of FDDS parameters, including size, shape, and composition. It guarantees that the FDDS stays buoyant in the stomach long enough to allow for optimum drug release by precisely computing the

floating force dynamics. By eliminating any potential fluctuations that can have an impact on intragastric buoyancy performance, this technology significantly improves its consistency and dependability [25-26].

Classification of Floating Drug Delivery System: -

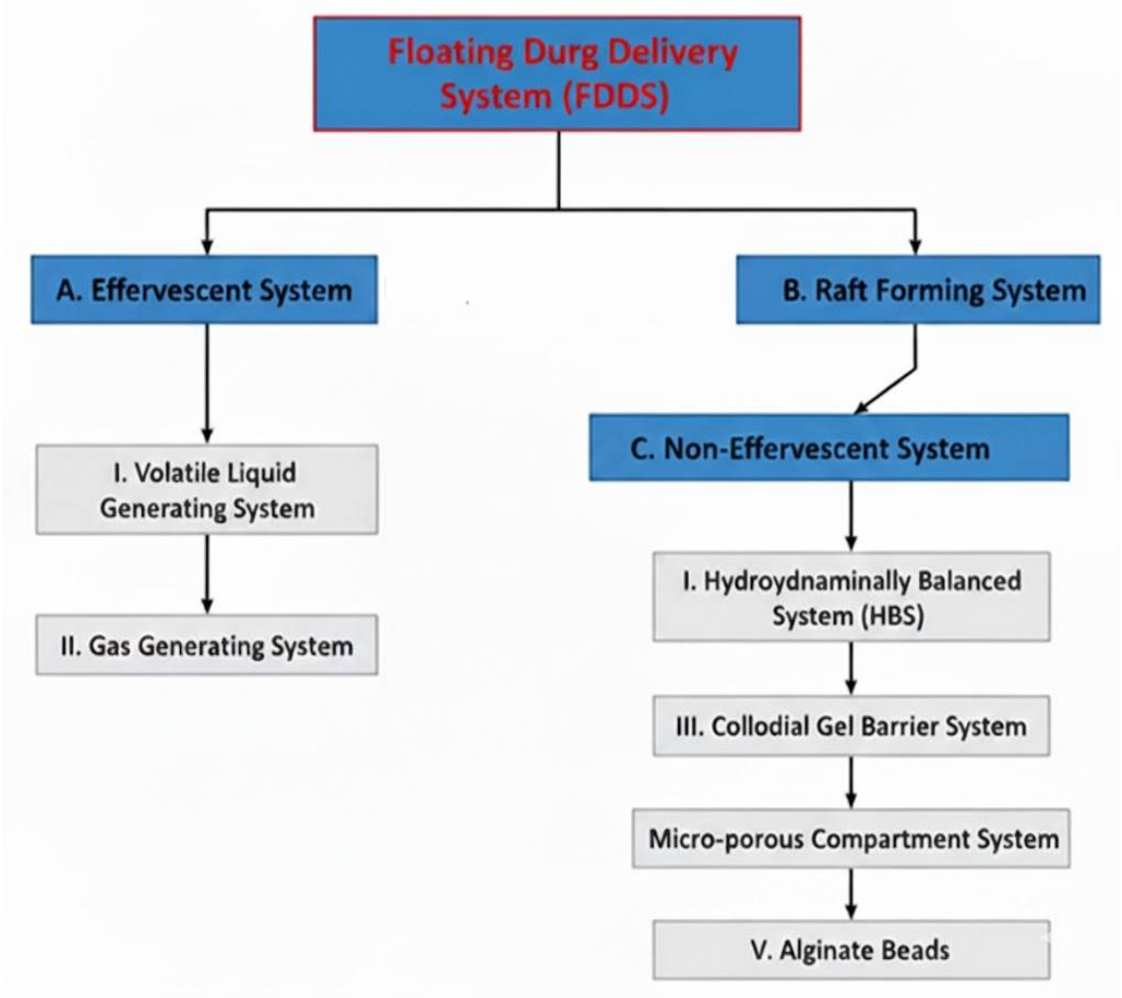

Fig. 02; Classification of FDDS

A. Effervescent System:-

Effervescent floating systems are made up of volatile liquids and a gas-generating agent. This method has been applied to both single- and multi-unit systems. Carbonates (sodium bicarbonate) and organic acids (citric acid and tartaric acid) react to generate carbon dioxide gas in the effervescent system, also known as the gas-generating system. Because of the gas produced, the dose form floats on top of the contents of the stomach. The two forms of effervescent floating systems are single- and double-layer effervescent floating tablets, as well as multiple-unit effervescent floating systems [28, 29].

I. Volatile Liquid Generating System:-

This is an osmotically floating system composed of a convertible, collapsed, hollow, deformable unit. Housing would be linked to a moveable, deformable, pressure-sensitive unit. The first chamber is usually filled with an active medication, while the second is filled with a volatile liquid such as. At physiological temperature, cyclo-pentane or ether vaporizes to form a gas, allowing the drug reservoir to float. It is discharged from the stomach via a biodegradable stopper that permits the vapour to escape [30, 31].

II. Gas Generating System:-

A gas-generating device is a type of floating medication delivery system that produces gas inside the dosage form when it comes into contact with stomach fluid. Gas generation allows for a longer gastric residency length, which also helps the dose form float on the gastric contents. This type of technique is frequently used in the development of effervescent floating formulae. Gas-generating systems offer a versatile system for achieving both extended stomach residency time and controlled medicine release. It is critical to carefully create the formulation so that gas generation is under control and the dosage form remains stable and effective for the period of its intended use [19, 32, 33].

B. Raft Forming System:-

The process by which a cohesive gel that is viscous forms in contact with stomach fluids causes each part of the liquid to swell and create a continuous layer known as a raft is one of the mechanisms underlying raft formation [34]. Anticipate a lot of interest in raft-forming technologies for the administration of antacids and medications for gastrointestinal ailments [35]. In order to create a raft layer on top of the gastric fluid and enable the medication to be released gradually into the stomach, a gel-forming solution expands when it comes into contact with gastric fluid and creates a viscous, cohesive gel entrapped with CO_2 bubbles [36].

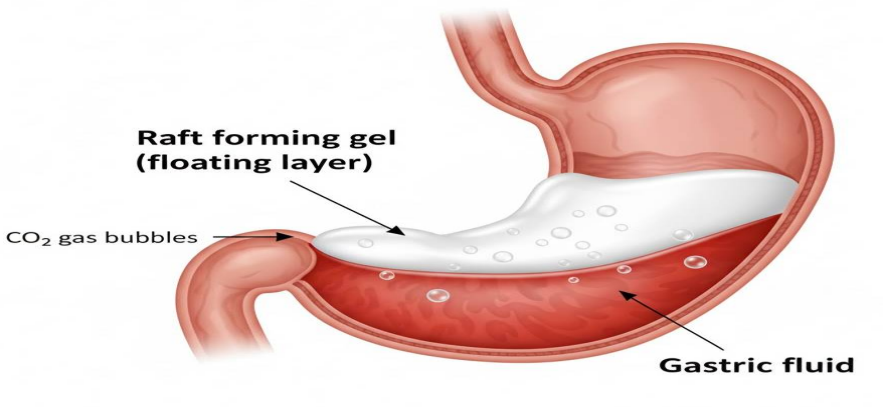

Fig. 04; Formation of Raft

These systems create a viscous gel or raft that floats on top of the stomach contents when they come into contact with gastric juice. Drug release is maintained with the help of the gel layer. The antacid raft-forming floating system contains a gel-forming agent (e.g., sodium alginate), sodium bicarbonate, and acid neutralizer, which come together to produce a foaming sodium alginate gel (raft), which floats on gastric fluids and minimizes reflux of gastric contents [37].

C. Non- Effervescent System:-

This kind of system swells uncontrollably after swallowing due to the uptake of gastric fluid and hence prohibits escape from the stomach. These systems are known as 'plug-type systems' because they tend to remain deposited near the pyloric sphincter. One way to develop such dosage forms is to combine the medication with a gel, which swells when it comes into contact with gastric fluid after oral administration and maintains relative shape integrity and a bulk density of less than one within the outer gelatinous barrier. The most widely utilized polymers in the formulation of these systems are HPMC, carbopol, polyacrylate polymers, and so on.

This system further classifield into following types; [38]

I. Hydro-dynamically Balanced Systems (HBS)
II. Colloidal Gel Barrier System
III. Bilayer Floating Tablet
IV. Micro-porous Compartment System
V. Alginate Beads

I. Hydro-dynamically Balanced Systems (HBS): -

In 1984, Sheth and Tossounian devised the Hydrophilic Buoyancy System (HBS), a monolithic system amalgamating the merits of both rigid and pliable frameworks [39]. The HBS system marked a paradigm shift in the realm of management by furnishing a holistic methodology for addressing predicaments and facilitating decision-making. It amalgamates quantitative scrutiny with qualitative insights, empowering managers to formulate more enlightened and efficacious decisions. This pioneering system has garnered widespread adoption across diverse industries, augmenting organizational capabilities to confront intricate challenges and attain desired objectives.

The pharmaceutical dosage form is constituted by hydrophilic polymers with gel-forming properties, such as hydroxyethylcellulose, hydroxypropyl methylcellulose (HPMC), and hydroxypropyl cellulose (HPC) [40]. The medication, together with the polymer, is encapsulated within a gelatin capsule, with bulk density deliberately maintained below 1 g/cm^3. The hydrodynamic attributes of the system facilitate buoyancy, enabling controlled release of the medication within the gastrointestinal tract [41].

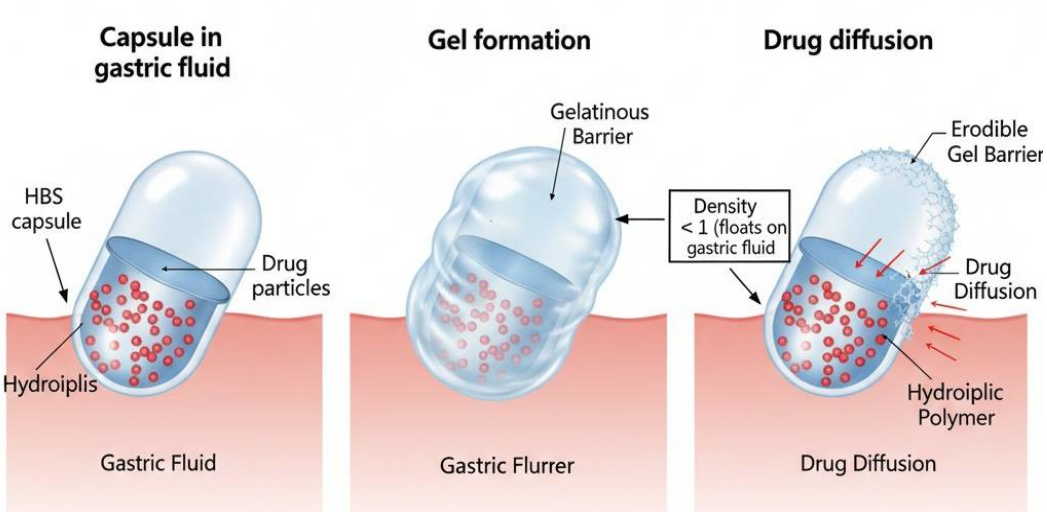

Fig.05; Hydro-dynamically Balanced Systems (HBS)

This delivery approach proffers advantages such as prolonged drug release, diminished dosing frequency, and heightened patient adherence. The hydrophilic polymers within the dosage form confer stability, shielding the medication from degradation and ensuring its efficacy throughout the release trajectory. In essence, this innovative drug delivery system represents a promising avenue for enhancing therapeutic outcomes and patient satisfaction. The equilibrium of mic balance prevents the system from sinking or rapidly transiting through the stomach [42].

II. Colloidal Gel Barrier System: -

The colloidal gel barrier system represents an advanced drug delivery modality employing hydrophilic polymers such as hydroxypropyl methylcellulose (HPMC) and sodium alginate to form a protective enclosure around the dosage form.[43] This innovative system is designed to prolong the residence time of the drug within the gastrointestinal tract while precisely regulating its release kinetics, thereby mitigating the likelihood of suboptimal absorption. The buoyant nature of the colloidal gel, characterized by its low density, facilitates its suspension atop the gastric contents, affording a controlled and gradual release of the drug [44]. Colloidal gels, characterized by a three-dimensional network structure comprising dispersed particles, are instrumental in this system. Gel formation is achieved through the cross-linking of hydrophilic polymers, creating a stable matrix that entraps fluids like water.

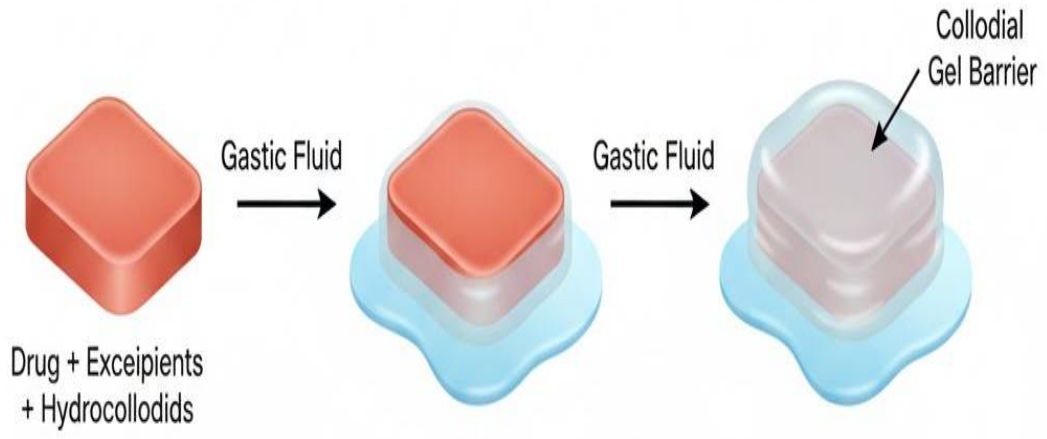

Fig. 06; Formation of colloidal barrier around drug

This matrix, acting as a robust barrier, captures the drug molecules, preventing their rapid dissolution or dispersion into the surrounding fluids [45]. Consequently, the drug is liberated in a gradual and sustained manner, ensuring a controlled release over an extended temporal horizon. This controlled release mechanism not only optimizes drug absorption but also diminishes the necessity for frequent dosing, thereby enhancing patient compliance and convenience. In summary, the colloidal gel barrier system stands as an advanced pharmaceutical delivery strategy, leveraging hydrophilic polymers and three-dimensional colloidal gels to achieve prolonged drug residence, controlled release, and improved therapeutic outcomes [46, 47].

III. Bilayer Floating Tablet: -

Typically, a tablet has two separate layers, each of which is responsible for delivering a different medicine. Three layers: buoyancy, drug-containing, and coating/barrier [48].

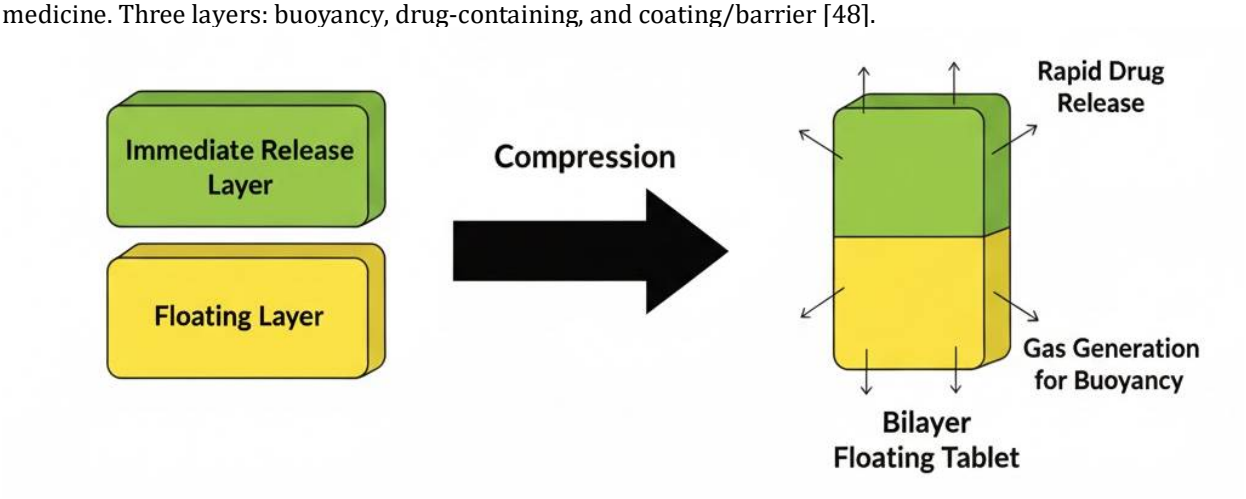

Fig. 07;Bilayer floating tablet

Buoyancy layer: The tablet's bottom layer is intended to provide stomach buoyancy. To keep the tablet floating, this layer contains elements with low density or compounds that produce gas, including effervescent agents. Acidic stomach juice and a carbonate or bicarbonate salt found in the buoyancy layer may react, producing gas [49, 50].

Drug-containing layer: The top layer of the tablet contains a medicine or a therapeutic composition. This layer is responsible for the drug's-controlled release. A variety of drug release mechanisms, including matrix erosion, diffusion through a matrix, and mixtures of these, can be used [51].

Coating/barrier: A third layer or coating might be added in some circumstances to give the drug release more control. This layer may serve as a barrier, delaying the drug's release until the tablet floats for a sufficient amount of time. It's possible that the coating is made to be pH-sensitive, reacting to the stomach's acidic environment [23, 52, 53].

IV. Micro-porous Compartment System:

Hollow microspheres laden with pharmaceutical agents were synthesized employing an innovative emulsion solvent diffusion technique. In this process, a solution comprising the drug dissolved in ethanol/dichloromethane and an enteric acrylic polymer was introduced into a thermally regulated, agitated polyvinyl alcohol solution at 40°C. The evaporation of dichloromethane resulted in the generation of a gas phase within the polymer droplet, creating an internal void within the drug-polymer microsphere. Subsequently, the microspheres, endowed with this unique internal structure, levitated over a surfactant for a duration exceeding 12 hours [26, 54, 55].

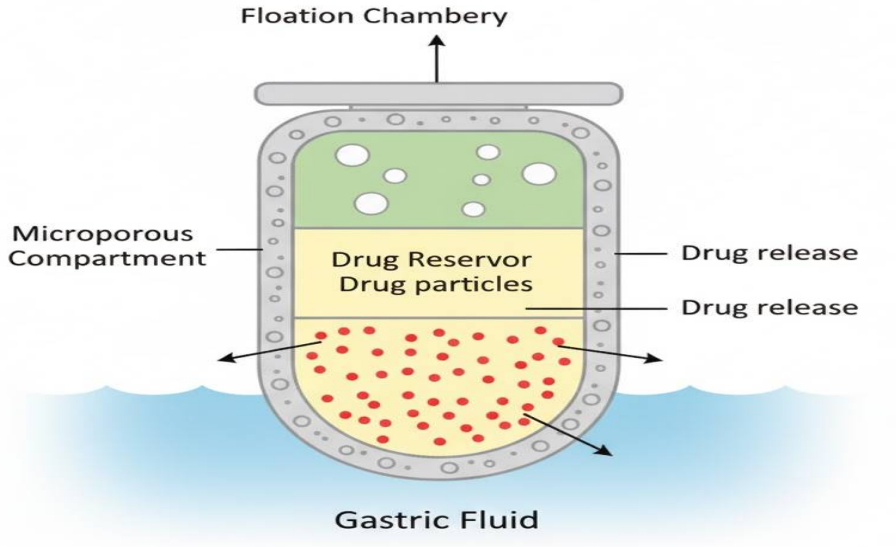

Fig. 08; Microporous Compartment System

This unique technique ensured a prolonged and reliable therapeutic effect by allowing the pharmaceutical substance to be released from the hollow microspheres in a regulated and sustained manner. The microspheres' internal cavity was coated with a surfactant, which improved their stability and served as a barrier to stop the medicine from releasing prematurely [56]. To summarize, the emulsion solvent diffusion technique was employed to create hollow microspheres, which offered a new way to achieve controlled drug release and extend therapeutic efficacy. Additionally, the surfactant encapsulation improved stability. Furthermore, the use of surfactants also enhanced the bioavailability of the medicine [57].

V. Alginate Beads:

Calcium alginate beads are generated through the conversion of sodium alginate into calcium alginate beads via ionic cross-linking with calcium ions, resulting in a more enduring and structurally resilient bead matrix [58]. This method encompasses the dissolution of sodium alginate in a suitable solvent, the integration of the intended drug or payload, and the extrusion of minute droplets into a calcium chloride solution. Subsequently, the beads undergo a washing process with distilled water to eliminate surplus calcium chloride and sodium alginate. The enhanced stability and mechanical strength of calcium alginate beads position them as pivotal components in various applications, notably in controlled drug delivery systems, encapsulation of bioactive compounds, and within the realms of pharmaceutical and biotechnological undertakings. Their augmented stability and mechanical robustness render them particularly well-suited for scenarios necessitating protracted drug release. Moreover, their inherent biocompatibility and capacity to encapsulate a diverse array of bioactive compounds contribute to their versatility and prominence in the domains of pharmaceutical and biotechnological research [59, 60].

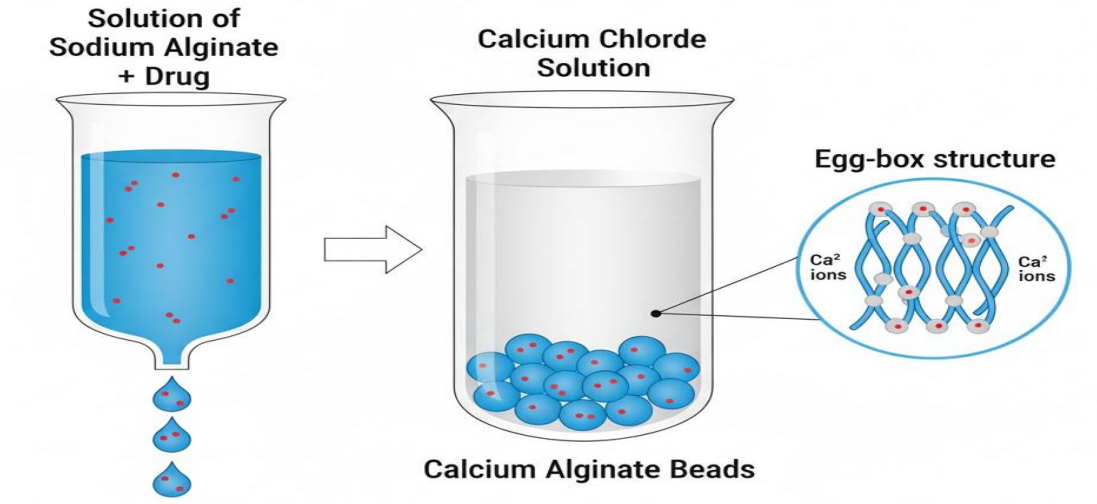

Fig. 09; Formation of alginate beads

Role of alginate beads in a floating drug delivery system; Gel Formation: Alginate has the ability to create a gel when it comes into contact with divalent cations, such as calcium ions [61]. When calcium ions are present, alginate molecules cross-link to create a three-dimensional gel structure. The beads have some mechanical strength because of the gel composition. Alginate beads can be made to float because of their low density [62]. Their buoyancy can be further increased by adding effervescent or gas-generating substances. Alginate beads can stay in the stomach for a longer period of time since they float on the gastric fluid due to their buoyancy [2, 63, 64].

Important Aspects of Floating Drug Delivery Systems: -

The development of floating medication delivery devices is an important milestone in pharmaceutical science. This novel method of administering medication tackles issues related to traditional drug administration and has the potential to enhance treatment results, particularly for medications requiring particular conditions for intestinal absorption [65].

a. **Buoyancy: -**Because FDDS is less dense than stomach contents; it is intended to float on gastric fluid. Usually, low-density polymers or gas-generating substances like effervescent agents are used to create this buoyancy [66].
b. **Gastrointestinal Retention: -** FDDS improves drug absorption from the gastrointestinal tract, particularly for medications with absorption restrictions in the upper gastrointestinal tract, by extending the resident time in the stomach [67].

c. **Controlled Drug Release:** The system is designed to release the medication over an extended period of time in a regulated way. In addition to ensuring a prolonged therapeutic effect, this regulated release profile may lessen the frequency of drug delivery [30, 68].

Advantages of Floating Drug Delivery System: -

1. Higher bioavailability may lead to more favourable treatment outcomes and fewer adverse effects.
2. Extended holding in the stomach.
3. Reduce alterations in plasma drug concentrations, resulting in a steadier and predictable drug release profile.
4. Lower the frequency of medication delivery to increase patient compliance.
5. Drugs can be released at pre-set times from FDDS, allowing Chronotherapy (timed drug administration) to correspond with the circadian rhythms of specific disorders [69]**.**
6. Medications having restricted solubility, as they can be made to deliver the medication gradually, improving absorption [70].
7. FDDS can be developed in a variety of dosage forms, including tablets, capsules, and multi-particulate systems, giving drug delivery designers more choice. This adaptability enables customization based on the drug's individual features and the desired release profile [2, 26, 32].

Disadvantages of Floating Drug Delivery System: -

1. Prolonged gastrointestinal residence time may raise the risk of irritation and harmful effects on the gastric mucosa, especially if the medicine contains irritant [71].
2. Individuals' stomach emptying times may differ significantly. This range may have an impact on the efficacy of FDDS as well as the consistency of medication release [72].
3. Food consumption can influence the gastric emptying rate, potentially influencing FDDS floating behaviour and medication release kinetics. This makes predicting drug release patterns in the presence of food difficult [73].
4. The patient's position, whether they are standing or lying down, can affect how the dosage forms float. A change in drug release may arise from alterations in the contact between the stomach fluid and the dosage form [74].
5. FDDS might not pass through the stomach entirely, which could cause build up and possible issues, including gastric bezoars. Long-term usage may raise concerns about this [75].
6. Achieving a prolonged release profile from FDDS may be difficult for medications with limited water solubility, as these compounds may not dissolve easily in gastric juices [76].
7. A few patients may struggle to adhere to floating dosage-form dosing regimens, potentially leading to medication adherence concerns. Despite these obstacles, continued research and formulation have led to breakthroughs [77].

FDDS FEATURES

Floating drug delivery systems have an impact on both the pharmacokinetic and pharmacodynamics features of drug delivery (FDDS). [5]

Pharmacokinetic features:

Absorption: Enhanced Bioavailability: By extending the time a medicine spends in the stomach, FDDS can improve drug absorption. This is especially advantageous for medications that are mostly absorbed in the stomach or those with low solubility.

Distribution: Stable Plasma Levels: FDDS helps to reduce fluctuations in plasma drug levels that may arise from conventional dose forms by offering controlled and prolonged drug release.

Metabolism: Stable Metabolism: The extended release of FDDS may expose the medication to metabolizing enzymes for an extended period of time, which may have an impact on drug metabolism. This is particularly important for medications that the liver metabolizes.

Elimination: Prolonged Elimination Half-Life: The sustained release of the medication from FDDS may result in a longer elimination half-life, which could lengthen the duration of therapeutic activity [78, 79].

a. **Pharmacodynamics features**:

1. Prolonged Therapeutic Effect
2. Improved Therapeutic Effectiveness
3. Reduced Side Effects
4. Timed Drug Delivery
5. Reduced Dosing Frequency and increase patient compliance.
6. Targeting Specific Sites [80, 81]

TYPES OF DOSAGE FORMS AVAILABLE FOR THE FLOATING DRUG DELIVERY SYSTEM

In the domain of pharmaceutical preparations, various dosage forms leverage floating technology to enhance patient compliance and facilitate controlled drug release. The enumeration below delineates distinct formulations employing this technology, offering examples of associated medications and elucidating their respective applications. Notable dosage forms encompassing floating technology include floating microspheres, floating capsules, and gastroretentive tablets. These formulations prove particularly advantageous for drugs necessitating targeted delivery within specific segments of the gastrointestinal tract or prolonged retention in the stomach. One illustrative example is Metformin XR, among other gastroretentive pills, designed to remain buoyant in the stomach. This buoyancy attribute allows for a gradual release of the medication over an extended period of time, leading to sustained therapeutic effects. Floating technology thus emerges as a valuable tool in pharmaceutical formulations, contributing to the optimization of drug delivery strategies and the improvement of therapeutic outcomes.[82-83]

a. Floating Granules: - For floating drug distribution, granules made of low-density materials or gas-generating agents can be manufactured. The granules are able to be compressed into pills or added to capsules.[84]

b. Floating Microspores: - It is also called floating microballons. Gas-generating agent-filled microspheres are encased in a polymer matrix. These microspheres deliver regulated drug release by floating in the stomach.[85-86]

c. Floating Films: - Floating films, also known as bilayer tablets, embrace two layers: one for immediate release and one for buoyant, sustained release. The floating layer contains gas-producing agents.

d. Floating Tablets and Pills: -Dosage forms that are solid and contain gas-generating substances that generate buoyancy. Polymers may be used in the tablet matrix to allow for regulated drug release. Floating pills are now a highly effective way to increase a drug's bioavailability, provide it with a continuous release, and prevent many of its side effects.

e. Floating Capsules: -Like floating tablets, but with the drug enclosed in a shell made of gelatine or another polymer. Agents that produce gas are frequently present in capsule components.[87]

Table No. 02: A list of pharmaceuticals examined in floating dosage forms;

Sr. No.	Type	Example	Uses
1	Floating Granules	Diclofenac sodium, Indomethacin, Prednisolone, Ranitidine Hydrochloride Gelucire	Gastrointestinal drug delivery for prolonged and controlled release.
2	Floating Microspheres	Aspirin, Ibuprofen, Captopril, Cimetidine	Extended-release formulations for improved bioavailability and therapeutic efficacy.
3	Films	Cinnarizine, Albendazole	Buccal or sublingual drug delivery, providing a controlled release for systemic absorption.
4	Floating Tablets/Pills	Acetylsalicylic acid, Amoxicillin trihydrate, Atenolol, Fluorouracil, Prednisolone, Theophylline, Verapamil HCL	Oral drug delivery with sustained release, suitable for various therapeutic indications.
5	Floating Capsules	Furosemide, Misoprostol, L-Dopa, Pepstatin, Propranolol	Gastroretentive drug delivery, ensuring prolonged gastric residence time for sustained action.

Table No.03 Floating Drug Delivery System Marketed Products

Sr. No.	Brand Name	Delivery System	Drug	Company
1	Gaviscon®	Effervescent floating liquid	Aluminium hydroxide, Mg Carbonate	Glaxo Smithkline, India
2	Topalkan®	Floating liquid alginate	Al – Mg antacid	Pierre Fabre Drug, France
3	Cifran OD®	Gas-generating floating form	Ciprofloxacin	Ranbaxy, India
4	Conviron®	Colloidal gel forming FDDS	Ferrous sulphate	Ranbaxy, India
5	Valrelease®	Floating Capsule	Diazepam	Hoffmann-LaRoche
6	Modopar® HBS	(Prolopa® HBS) Floating, CR capsule	Benserazide and L – Dopa	Roche Products, USA
7	Cytotech®	Bilayer floating capsule	Misoprostol	Pharmacia, USA

1. Strategies for developing dosage forms that the gastrointestinal tract can retain: -

Designing dosage forms that can be retained in the gastrointestinal (GI) tract is crucial for optimal drug delivery. Floating Capsules The strategies for achieving this goal vary depending on the specific characteristics of the drug and the desired release profile. Here are some common strategies [88]:

A. Gastro-retentive Formulations

a. Floating Systems: -Formulations incorporating buoyant ingredients, like low-density polymers or gas-generating agents, float on the contents of the stomach.

b. Bio-adhesive Systems: - Dosage forms may be attached to the gastrointestinal mucosa, increasing contact time and stomach retention. This can be accomplished by employing bio-adhesive polymers.

c. Swelling Systems: -Formulations that swells or expands as they come into contact with stomach fluid result in greater size and decreased density, which aids with retention.

B. Size Modification: -Developing dose forms that are too large to easily pass through the pyloric sphincter, causing them to remain in the stomach. This can be accomplished by employing matrix systems or multi-particulate formulations.

C. Osmotic Controlled Release: -Regulating medication release by means of osmotic pressure. Controlled drug delivery is achieved by permitting water to enter the system and releasing the drug gradually through osmotic pumps or tablets.

D. Interpenetrating Polymer Networks (IPN): -

Developing matrices of polymers that balance mechanical strength and swelling enhances the dosage form's long-term reliability and retention.

E. Combination Approaches: -

Amalgamating several techniques to produce a dose form with the best features for stomach retention. This could incorporate a multi-particulate system with pH-dependent release or a floating system with bio-adhesive qualities [89, 90].

FUTURE PROSPECTIVE OF FLOATING DRUG DELIVERY SYSTEM

Future floating medication delivery systems will have a dynamic, multidisciplinary focus on technology, medicines, and materials research. Further developments in these fields have the potential to upend preconceived notions about medication delivery and lead to more efficient and patient-focused healthcare options. The extensive implementation of advanced drug delivery systems in clinical practice has been facilitated by regulatory frameworks, remote monitoring, and quicker approval processes. These factors have also increased patient adherence. These developments have also made targeted medication delivery and personalized therapy possible, leading to more effective therapies with fewer adverse effects. Furthermore, the accuracy and efficiency of medication creation and patient care have been significantly improved by the integration of big data analytics and artificial intelligence [91].

CONCLUSION

The Floating Drug Delivery System (FDDS) serves as a pivotal investigation into buoyancy principles for achieving prolonged stomach preservation. Understanding the dynamics of the gastrointestinal tract is crucial to comprehending the behaviour of medications in the digestive environment. Various processes, guided by buoyant properties and principles, are employed in the production of floating tablets, encompassing both effervescent and non-effervescent formulations. FDDS proves particularly valuable for delivering drugs that face challenges in the lower intestine environment, possess a narrow absorption window in the upper gastrointestinal system, exhibit low solubility at higher pH levels, or act locally.

The primary aim of this review is to consolidate recent research findings, emphasizing the advantages and disadvantages associated with action mechanisms, preparation methods, and the classification of FDDS. The review encompasses a comprehensive exploration of the latest advancements in FDDS, considering physiological and formulation aspects influencing stomach retention, design strategies for floating systems incorporating one or more units, and the formulation and classification characteristics of these systems. By delving into these aspects, the review provides a thorough overview of the current state of research in FDDS, offering valuable insights into its potential applications and limitations.

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