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# A Comprehensive Review on Floating Drug Delivery System as A Novel Drug Delivery

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## ABSTRACT

Hydrodynamically controlled systems, also known as floating drug delivery systems (FDDS), are low-density devices with enough buoyancy to float over the contents of the stomach and stay buoyant there for an extended amount of time without interfering with the process of gastric emptying. The medication is gradually discharged from the system at the appropriate pace while it is floating on the stomach contents. The residual system is cleared from the stomach following the drug's release. Increased GRT and improved control over variations in plasma medication concentration are the outcomes of this. However, a minimal degree of floating force (F) is also necessary to maintain the dose form consistently buoyant on the meal's surface, in addition to the minimal stomach content needed to enable the correct implementation of the buoyancy retention principle. Granules, powders, capsules, tablets, laminated films, and hollow microspheres have all been used to create a variety of buoyant systems.

**Key Words:** *Hydrodynamically controlled systems, floating drug delivery systems (FDDS), GRT.*

## Introduction

One prerequisite for the successful operation of an oral controlled release drug delivery system is that the drug be well absorbed throughout the gastrointestinal tract (GIT), ideally by passive diffusion. Oral controlled release dose forms are unsuitable for a wide range of critical medications due to a tight absorption window in the upper part of the GI tract. The DF (dosage form) has a rather low transit time in certain anatomical segments. Thus, in less than 6 hours, the CR-DF (controlled release DF) has already exited the upper GIT, and the medication is released in a short, non-absorbing distal stretch of the GIT. This results in a brief absorption phase, which is followed by lower bioavailability. Pharmaceutical DF with gastroretentive qualities would allow these medications to have a protracted absorption phase despite their restricted absorption window. After oral delivery, DF would remain in the stomach and release the drug in a regulated and extended way, allowing the medicine to be delivered continually to its absorption sites in the upper GIT [1]. Another significant significance for the DF with lengthy residence time in the stomach is:

1) pharmaceuticals are locally active in the stomach, for example, pharmaceuticals used in the eradication of Helicobacter pylori, which is now recognized to be the causative bacterium for chronic gastritis and peptic ulcer, such as tetracycline [2].
2) Drugs are unstable in the intestinal or colonic environment, such as ranitidine [3].
3) Drugs have reduced solubility at high pH values, such as verapamil [4].

Approaches to increase the gastrointestinal residence duration of medication formulation include [5]:

i)Floating drug delivery systems (FDDS)
ii) A high-density medication formulation that stays at the bottom of the stomach.
iii) Bioadhesive devices;
iv) Systems that rapidly grow in size after ingesting, either by expansion or unfolding; and

v) Slowed gastrointestinal tract movement due to concurrent medication administration (propantheline). The current study focuses on the FDDS (Tables 1&2), which is one of the most advanced techniques in gastroretentive medication formulations. Non effervescent FDDS's most popular excipients are gel-forming or highly swellable cellulose hydrocolloids, polysaccharides, and matrix-forming polymers like polycarbonate, polyacrylate, polymethacrylate, and polystyrene. One of the floating formulations is a gel-forming hydrocolloid in a capsule that swells when in contact with gastric fluid following oral administration while maintaining relative shape integrity and a bulk density of less than unity within the outer gelatinous barrier [6]. The air contained by the inflated polymer adds buoyancy to these dose forms. When such DF comes into contact with an aqueous media, the hydrocolloid begins to hydrate by creating a gel, which regulates the rate of solvent and drug diffusion into and out of the DF. As the external surface of the DF dissolves, the neighboring hydrocolloid layer becomes hydrated, preserving the gel layer. As a result, the drug dissolves in and diffuses out with the diffusing solvent, leaving a receding border within a gel structure [7].

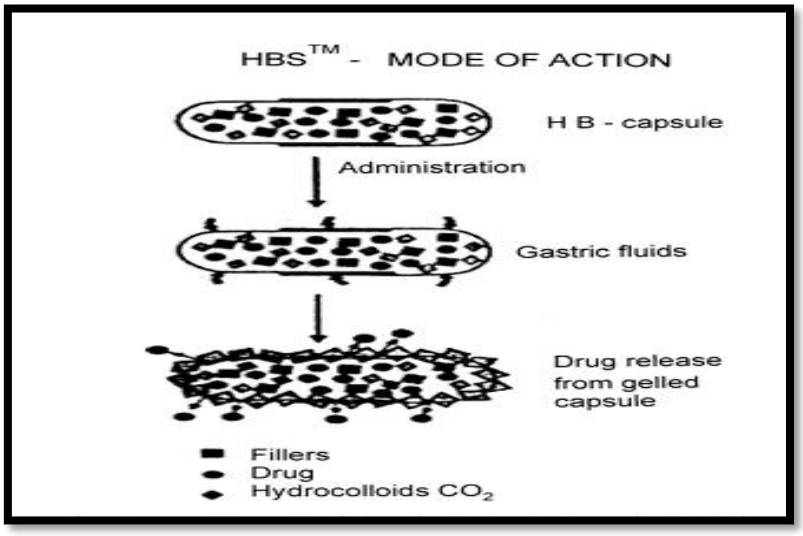


**Fig. 1- Working principle of the hydrodynamically balance system within the gel structure [8]**

When a capsule containing a medication and hydrocolloids comes into touch with gastric fluid, the capsule shell dissolves; the mixture swells and creates a gelatinous barrier, allowing it to remain buoyant in gastric juice for an extended amount of time [8] (Fig. 1). G D Searle and Co. described a bilayer buoyant dosage form made up of bilayer formulation9. One layer was a drug release layer with misoprostol, while the other was a buoyant or floating layer. Each layer contained a hydrocolloid gelling agent, such as hydroxylpropylmethylcellulose (HPMC), gums, polysaccharides, and gelatin, which, when in contact with gastric juice, created a gelatinous mass sufficient to cohesively bond the drug release and floating layers. DF has been demonstrated to be buoyant in gastric fluid for up to 13 hours, resulting in a significant amount of medication released in the stomach [9]. Desai and Bolton [10, 11] created CR floating tablets of theophylline using agar and mild mineral oil. Dispersing a drug/oil mixture in a warm agar gel solution and putting it into tablet molds resulted in floatable CR tablets after chilling and air drying. The amount of agar required to create a floating tablet was very low (2% per tablet). Because relatively large volumes of medication (75%) were used, light mineral oil was required for the tablet's flotation. Second, the intrinsic hydrophobicity of the light mineral in the formulation prevents entrapped air from escaping. Dennis et al. [12] proposed a buoyant CR powder formulation that could be packed into capsules or compacted into tablets. The formulation included a medication, a pH-dependent polymer (a water-soluble salt of alginic acid, such as sodium or potassium alginate), a pH-independent hydrocolloid gelling agent (such as HPMC, methyl cellulose, HPC, or a combination of the three), and a binder. The formulation was regarded remarkable in that it released the drug at a consistent rate independent of the pH of the environment, was free of calcium ion and CO2 generating material, and had drug release qualities similar to a tablet of the same composition. Mitra [13] proposed a multilayered, flexible sheet-like medicament device that was buoyant in gastric liquid and had SR properties. The device included at least one dry, self-supporting carrier film composed of a water-insoluble polymer matrix with a medicament distributed or dissolved within it, as well as a barrier film overlaid on top of the carrier film. The barrier film was made up of two polymers or copolymers: one water-insoluble and one that was both water- and drug-permeable. Both barrier and carrier films were sealed together along their periphery, trapping a number of small air pockets and resulting in the buoyancy of laminated films. Thanoo polycarbonate et al. [14] created drug-loaded microspheres using a solvent evaporation approach. This technique yielded a high drug loading of 50%. Kawashima et al. [15,16] used an emulsion solvent diffusion approach to create hollow microspheres ('microballoons') with a medicine injected into their outer shells (Fig. 2). An ethanol/dichloromethane solution comprising a medication and an enteric acrylic polymer was put into an aqueous solution of polyvinyl alcohol at 40°C. To generate emulsion droplets, the later solution was constantly agitated while the former was being added. The gas phase formed in the dispersed polymer droplet by dichloromethane

evaporation created an interior cavity in the polymer's microsphere containing the medicine. Harrigan [17] described an intragastric floating drug delivery system consisting of a drug reservoir encased in a microporous compartment with pores on the top and bottom surfaces. The peripheral walls of the drug reservoir compartment were entirely sealed to prevent any physical contact between the undissolved drug and the stomach walls. The Floatation Chamber caused the system to float in stomach fluid. Whitehead et al. [18] created a multiple-unit floating dose form using freeze-dried calcium alginate. Dropping a sodium alginate solution into aqueous calcium chloride produced spherical beads (about 2.5 mm in diameter). After internal gelation was completed, the beads were removed from the solution and snap-frozen in liquid nitrogen before being freeze dried at -40°C for 24 hours. The results of the weight measurements indicated that these beads maintained a positive floating force for more than 12 hours.

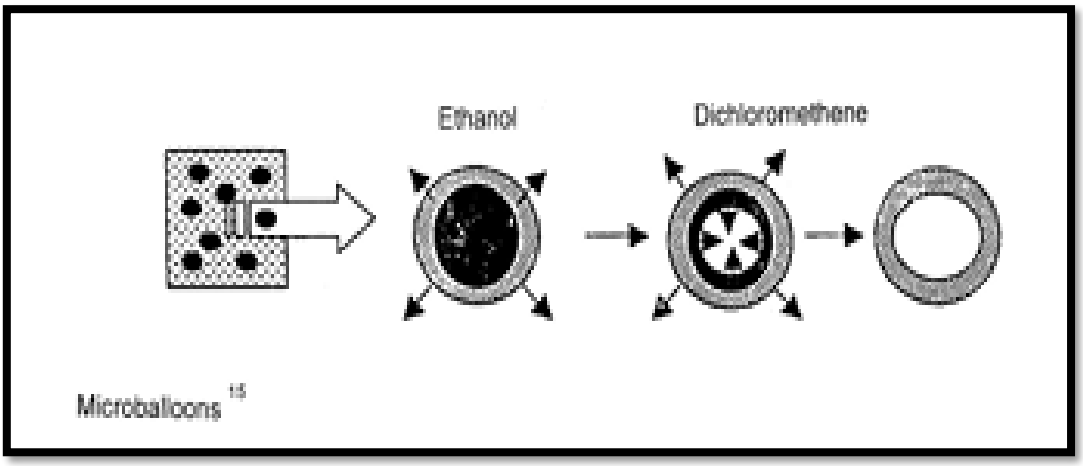


**Fig. 2- Microballoons [15]**

Krogel and Bodemeier [19] created a floating device made up of two drug-loaded HPMC matrix tablets that were inserted inside an impermeable, hollow polypropylene cylinder (open on both ends). Each matrix tablet closed one of the cylinder's ends, creating an air-filled space in the middle, resulting in a low total system density. The apparatus stayed afloat until at least one of the tablets dissolved. A recent method in FDDS uses low-density foam powder-based micro particles. This technology is useful because it has zero to negligible lag time before flotation begins. These floating microcapsules, created using the emulsion solvent evaporation process, include polypropylene foam powder, polymers (Eudragit SR/ethyl cellulose/methacrylate polymer), and a model medication (verapamil HCL). The drug release rate increases dramatically with each type of polymer in the following order: PMMA > EC > Eudragit SR.20. Another study on foam powder-based microcapsules investigates the effect of formulation and processing factors on drug release utilizing various matrix-forming polymers, such as HPMC, polyacrylates, Na-alginate, maize starch, carageenan, gum guar, and gum arabic. The study found that the release rate can be altered by adjusting the matrix forming polymer/foam powder ratio, initial drug loading, tablet shape (radius and height), matrix forming polymer type, polymer blends, and water soluble/insoluble fillers (lactose/MCC) [20].

**Basic Physiology of the GIT**

The stomach is anatomically divided into three parts: the fundus, body, and antrum (or pylorus). The proximal stomach, which includes the fundus and body regions, serves as a reservoir for ingested materials, whilst the distal region (antrum) is the primary site of mixing motions, working as a pump to complete gastric emptying. Fasting and feeding both cause gastric emptying. [21]

**Gastric emptying and difficulties**.

Scintigraphic investigations assessing gastric emptying rates revealed that orally administered controlled release dosage forms are prone to two major complications: short gastric residence time and unpredictable gastric emptying rates.

a. Gastric Residence Time [GRT] is short.

b. Gastric Emptying Time [GET] is variable and unpredictable [23].

In both fed and fasting states, the stomach empties. Nonetheless, the two states have different motility patterns. An interdigestive sequence of electrical events occurs during the fasting state, cycling through the gut and stomach every two to three hours. The interdigestive myloelectric cycle, also known as the migrating myloelectric cycle (MMC), is further broken down into the following four phases:

1. Phase I, also known as the basal phase, has few contractions and lasts between 40 and 60 minutes.

2. Phase II, also known as the preburst phase, consists of sporadic contractions and action potentials that last for 40 to 60 minutes. Both strength and frequency steadily rise as the phase goes on.

3. The burst phase, or phase III, lasts four to six minutes. It involves brief, frequent, and strong contractions. All of the undigested food is carried from the stomach to the small intestine by this wave. The housekeeping wave is another name for it.

4. Phase IV takes place in between phases III and I of two successive cycles, lasting 0 to 5 minutes. The contraction pattern shifts from a starved to a fed condition following the consumption of a mixed meal. This pattern, which is also referred to as the digestive motility pattern, consists of constant contractions similar to those that occur during phase II of fasting. Food particles are reduced in size to less than 1 mm as a result of these contractions, and they are then driven in a suspension form toward the pylorus. The stomach emptying rate slows down during the fed state because the beginning of MMC is delayed. [23] Every two to three hours, this sequence of electrical events starts in the foregut and travels to the terminal ileum when fasting. Postprandial motility is a continuous pattern of contractions and spike potentials triggered after feeding.[24]

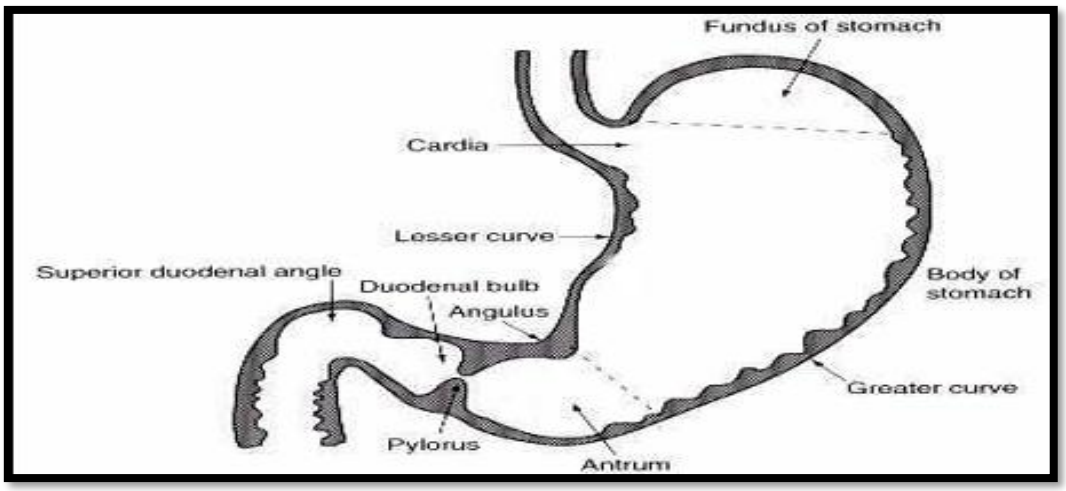


**Figure 3 : Anatomy of stomach [22]**

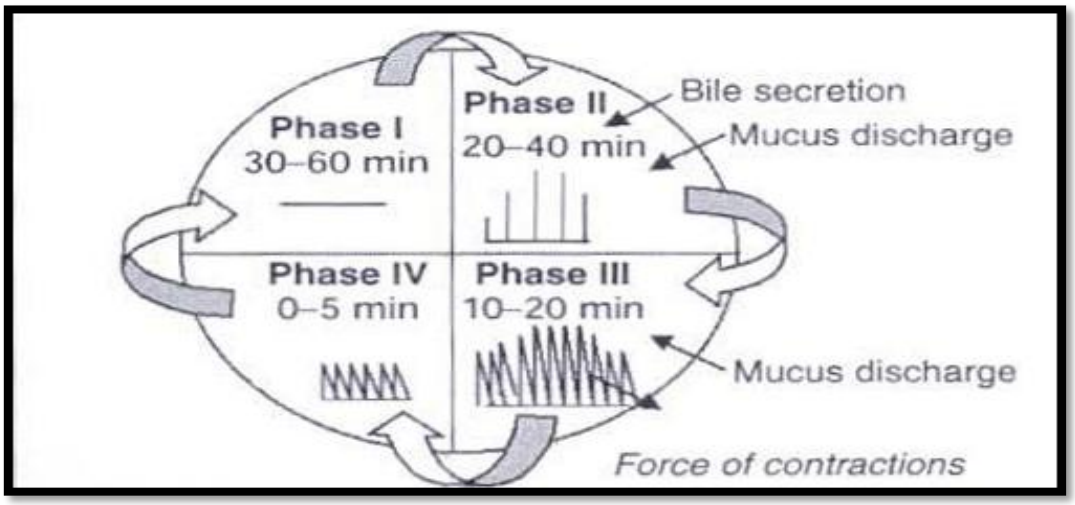


**Figure 4: Motility patterns of the GIT in the fasted state.[21]**

Perioral CRDDS and GRDDS performance is influenced by the specific phase in which a dose form is administered. The MMC may be in any of its phases when CRDDS is given during fasting, which can have a substantial impact on the GIT's transit time and total gastric residence time (GRT). Because it will impact how much time the dose form spends in the area before and around the window, this takes much greater significance for medications with an absorption window. The degree of absorption decreases with the amount of time spent in that area. The resistance of the dose form to gastric emptying during Phase III of the MMC in the fasting state and to continuous gastric emptying through the pyloric sphincter in the fed state should therefore be taken into account when designing GRDDS. This implies that GRDDS must be able to withstand the assault of physiological events for the necessary amount of time and work rapidly after injection.[21]

**PHYSICOCHEMICAL FACTORS IMPACTING GASTRIC RETENTION TIME [25]**

Dosage form size: Dosage forms that are larger than the pyloric sphincter's diameter avoid emptying the stomach and stay inside the stomach. Dosage form shape: Round or ring-shaped dosage forms are thought to be preferable.

Density: Location of the particular gastro retentive dosage form in gastric region depends on density of the system. While high density systems sink to the bottom of the stomach, low density systems typically float on the surface of the gastric fluid.

**BIOLOGICAL FACTORS**

**Age:**

Compared to a typical adult, the stomach retention period is lower in neonates and children and longer in elderly people

**Gender:**

Males have a shorter stomach retention time (3–4 hours) than females (4–6 hours).

**Fed or unfed state:**

When fasting, there is more gastric motility, which indicates a lower GRT.

**Frequency of feed:**

The GRT will be longer if food is consumed more frequently.

**Type of meal:**

By changing gastric motility, high levels of fatty acids and other indigestible polymers typically shorten the stomach retention period.

**State of illness:**

Many gastric disorders, such as Crohn's disease, cause changes in gastroretentive time.

**IDIOSYNCRATIC ASPECTS**

Concurrent administration of drugs:

Gastric retention duration and, consequently, the absorption of stomach-specific pharmaceuticals are significantly impacted when some medications are administered in conjunction with gastric motility enhancers (metoclopramide, cisapride) or depressants (atropine).

**DIFFERENT METHODS FOR GASTRIC RETENTION [23,25]**

1. Non-floating delivery or high density (sinking) systems
2. Floating delivery or low density systems
3. Bioadhesive/Mucoadhesive Systems
4. Systems that can be expanded
5. Systems of Superporous Hydrogel
6. Systems that are magnetic.

**The floating system's mechanism [22, 26]**

Because they have a lower bulk density than gastric fluids, floating drug delivery systems (FDDS) stay buoyant in the stomach for extended periods of time without interfering with the rate of gastric emptying. The medication is gradually removed from the system at the appropriate pace while it is floating on the stomach contents (Figure 5 (a)). The residual system is cleared from the stomach following the drug's release. Increased GRT and improved control over variations in plasma medication concentration are the outcomes of this. Nevertheless, aside from the minimal stomach content required to enable the correct use of the buoyancy retention principle, To maintain the dose form consistently buoyant on the meal's surface, a minimum amount of floating force (F) is also necessary. A unique device for determining resultant weight has been disclosed in the literature in order to assess the floating force kinetics. The device works by continually measuring the force corresponding to F (as a function of time) needed to keep the submerged object in place. If F is on the higher positive side, the object floats more easily (Figure 5(b)). In order to avoid the negative effects of unpredictable intragastric buoyancy, this device aids in optimizing FDDS with regard to stability and durability of floating forces generated. Variations in capability

$$F = F_{buoyancy} - F_{gravity}$$
$$= (Df - Ds)\, g * v$$

Where,

F= total vertical force,

Df = fluid density,

Ds = object density,

v = volume and g = acceleration due to gravity.

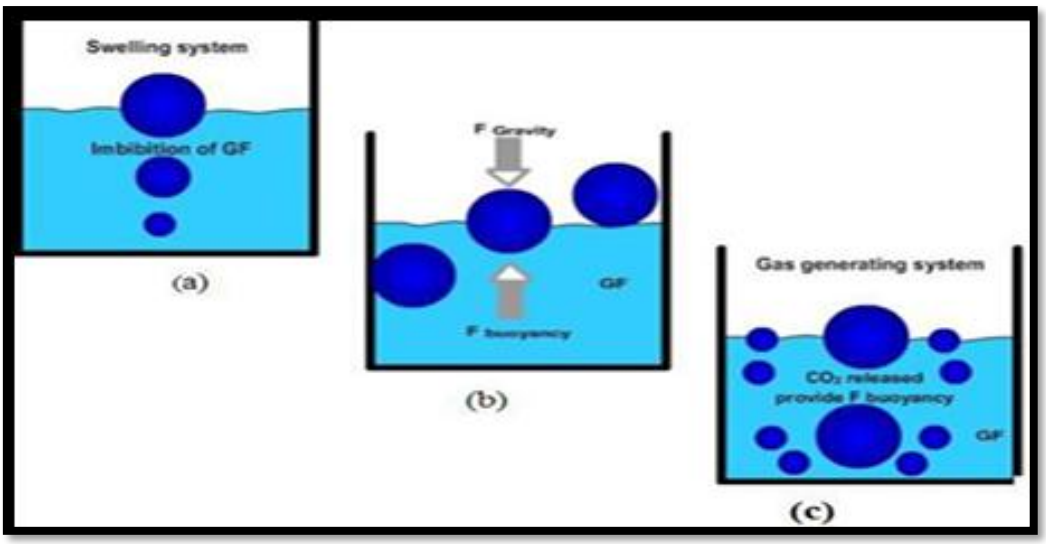


**Figure 5 :Mechanism of floating systems, GF= Gastric fluid [26]**

**Methods for Creating Flotting Dosage Forms**

Floating dosage forms for single and multiple unit systems have been designed using the following methods.[27]

**Forms of Single-Unit Dosage**

The globular shells, which appear to have a lower density than stomach juice, can be utilized as a drug carrier for controlled release in low density techniques [28]. A fluid-filled device that floats in the stomach can also be used to produce a buoyant dose form. Popcorn, poprice, and polystyrol have been used as drug transporters in coated shells [29]. These shells have been undercoated with sugar polymeric materials such cellulose acetate phthalate and methacrylic polymer. A drug-polymer mixture is applied on top of these. Depending on the desired form of release, the polymer of choice can be either hydroxyl propyl cellulose or ethyl cellulose. Ultimately, the product releases the medication gradually over a long period of time while floating on the gastric juice. A gas-filled floatation chamber is incorporated into a microporous component that contains a drug reservoir in fluid-filled floating chamber dosage forms. [30]

**DOSAGE FORMATS WITH MANY UNITS**

Creating a dependable formulation with all the benefits of a single-unit form and none of the aforementioned drawbacks of single-unit formulations is the goal of inventing multiple-unit dosage forms. Numerous multiple unit floatable dose forms have been created in an effort to achieve this goal. Numerous polymers, including albumin, gelatin, starch, polymethacrylate, polyacrylamine, and polyalkyl cyano acrylate, have been employed in microspheres due to their high loading capacity. "Microballoons," which are spherical polymeric microsponges, have been created. Microspheres have exceptional in vitro floatability and a distinctive interior hollow structure.[31] If the extended diameter of these dose forms exceeds around 12 to 18 mm, they are not allowed to pass through the pyloric sphincter.

**FLOATING DRUG DELIVERY SYSTEM (FDDS) CLASSIFICATION [32,22,33-36]**

Two very different technologies have been used in the creation of FDDS based on the buoyancy mechanism:

- Effervescent Systems
- Non-Effervescent Systems

**EFFERVESCENT FDDS.**

These buoyant drug delivery methods use matrices made from swellable polymers like Methocel® or polysaccharides like chitosan, as well as effervescent components.Carbonates (e.g., sodium bicarbonate) and other organic acids (e.g., citric acid and tartaric acid) in the formulation produce carbon dioxide (CO2) gas as a result of the acidity of the gastric content, which is entrapped in the gellified hydrocolloid, reducing the density of the system and causing it to float on the gastric fluid. An approach is to incorporate a matrix holding a percentage of liquid, which generates gas that evaporates at body temperature. These effervescent systems are further divided into two types:

- Gas-generating systems.
- Volatile liquid/vacuum containment systems.

I. **SYSTEMS FOR GAS GENERATION**

**1. Hydrodynamically balanced systems (HBS) or intragastric single layer floating tablets**

These are made by thoroughly combining the medication and CO2-generating chemicals inside the matrix tablet (Figure 6). Because they have a lower bulk density than gastric fluids, they float in the stomach for a longer amount of time, which detracts from the gastric emptying rate. The residual system is eliminated from the stomach once the medication has been gradually withdrawn from the floating system at the proper rate. As a result, the GRT rises and fluctuations in plasma drug concentration are better controlled.

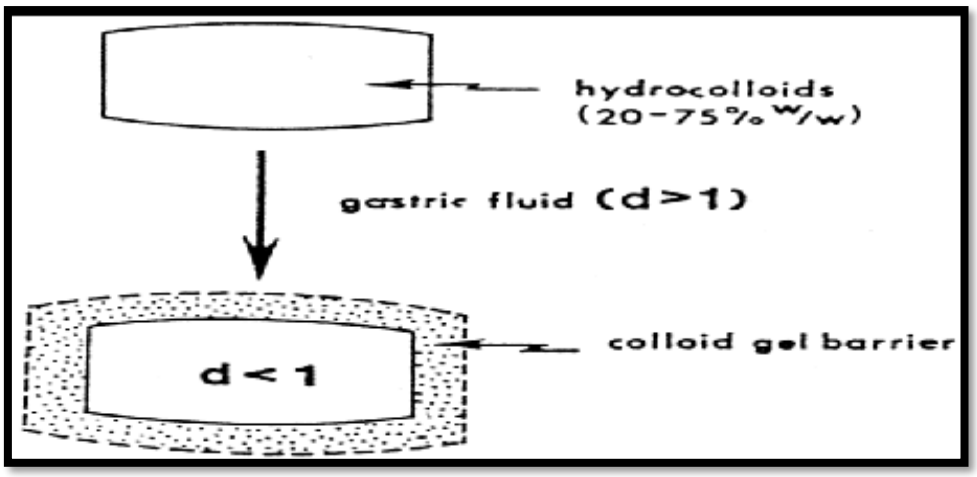


**Figure 6 : Intra-gastric floating tablet [34]**

**2. Bilayer floating pills within the stomach**

These have two layers and are also compressed tablets (Figure 7). Layers of immediate and sustained release.

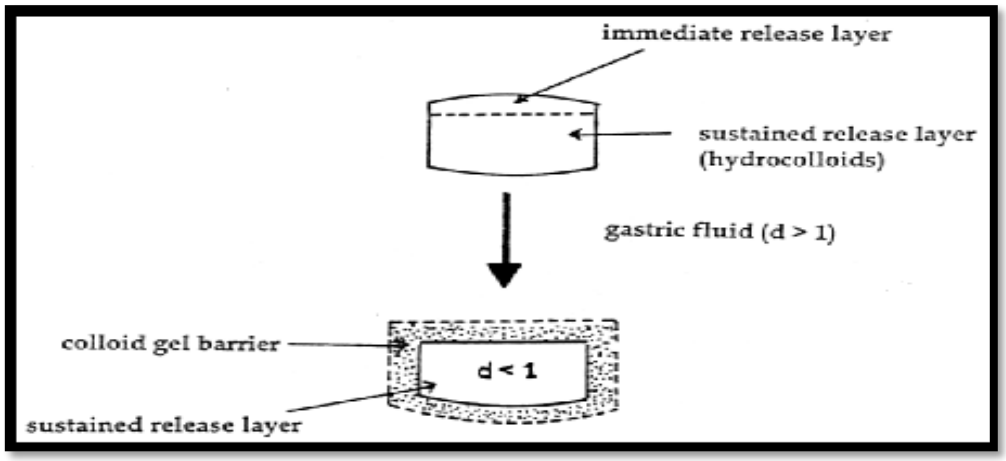


**Figure 7 :Intra-gastric floating bilayer tablet [35]**

**3. Floating pills with many unit types**

These systems are made up of double-layered sustained-release pills that act as "seeds" (Figure 8(a) and (b)). Effervescent agents make up the inner layer, and a swellable membrane layer makes up the outer layer. The system immediately sinks when submerged in a dissolving solvent at body temperature, forming bloated pills that resemble balloons and float because of their reduced density. The production and entrapment of CO2 within the system is the cause of this reduced density.

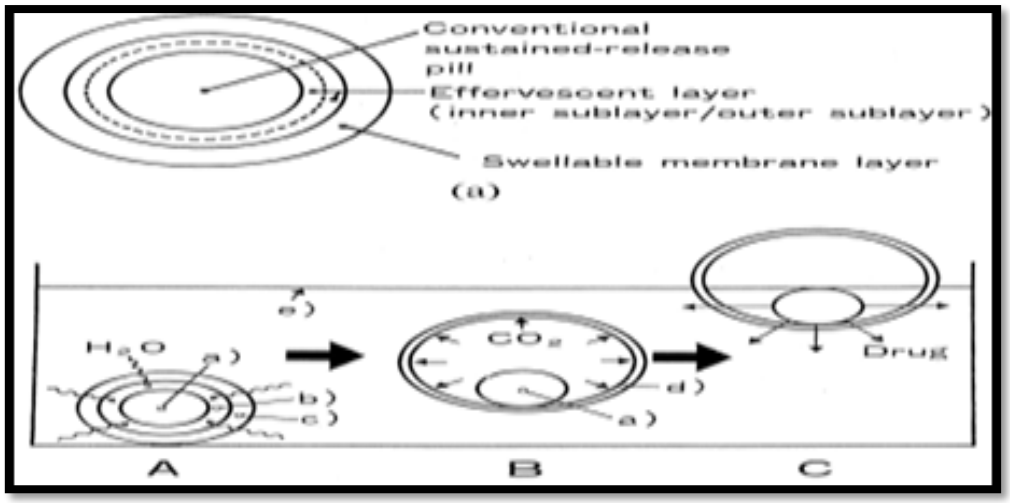


**Figure 8: (a) A multiple-unit oral floating dosage system.[36]**

**Figure 8: (b) Floating mechanism stages: (A) water penetration; (B) CO2 generation and floating; and (C) medication dissolution. Key: (a) traditional SR tablets; (b) effervescent layer; (c) swellable layer; (d) enlarged swellable membrane layer; and (e) water surface in the beaker (37 0C).[36]**

**II. VACUUM CONTAINING SYSTEMS AND VOLATILE LIQUID**

**1. The intragastric floating gastrointestinal medication delivery system**

The drug reservoir is contained within a microporous compartment, and the floating chamber—which can be vacuum-filled or filled with air or a safe gas—allows this device to float in the stomach.

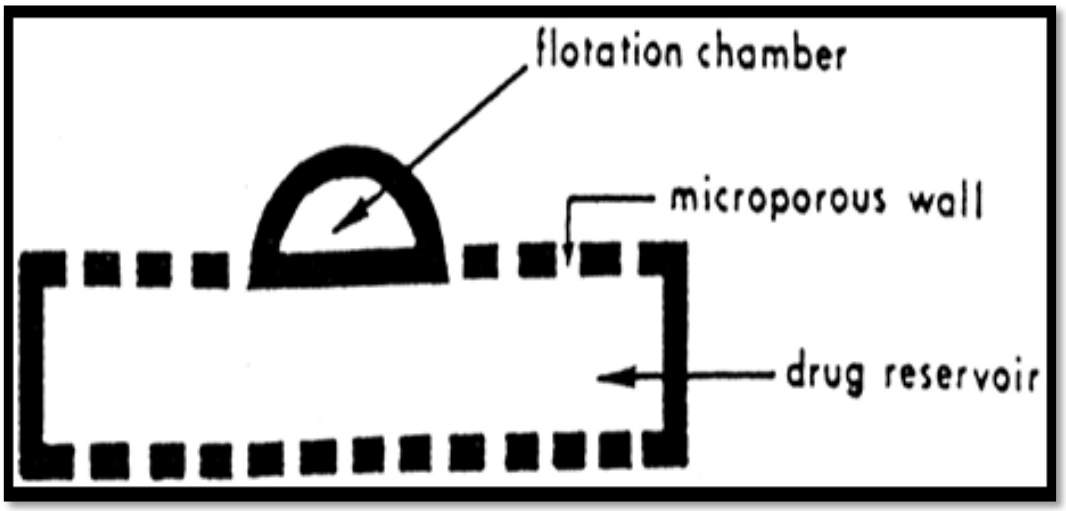


**Figure 9 : Intragastric floating drug delivery device [34]**

**2. Gastrointestinal delivery systems that are inflatable**

These devices include an inflatable chamber that expands in the stomach due to the gasification of liquid ether at body temperature. In order to create these systems, a drug reservoir—which may be a drug or an impregnated polymeric matrix—is loaded into the inflated chamber and then placed within a gelatin capsule. The medication reservoir and inflated chamber are released when the capsule dissolves after oral administration. The medication was continually delivered into the stomach fluid from the reservoir (Figure 10).

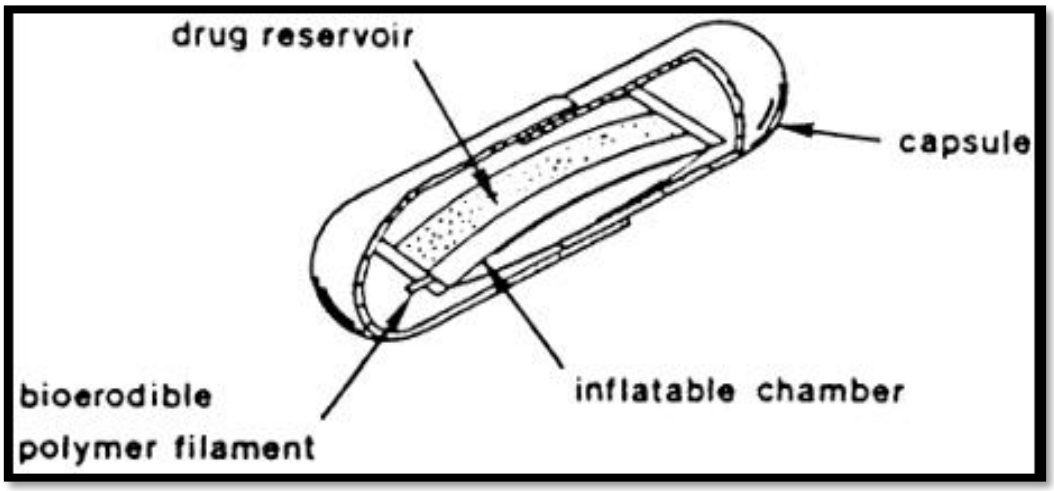


**Figure 10 : Gastro-inflatable drug delivery device [36]**

**3. Osmotically regulated intragastric medication delivery system**

It consists of a biodegradable capsule with an inflated floating support and an osmotic pressure-controlled drug delivery system. The intragastirc osmotically regulated medication delivery mechanism is released when the capsule rapidly breaks down in the stomach. The deformable hollow polymeric bag formed by the inflatable support within is filled with a liquid that gasifies at body temperature to cause the bag to expand. Drug reservoir compartments and osmotically active compartments make up the two parts of osmotic pressure-controlled drug delivery devices.

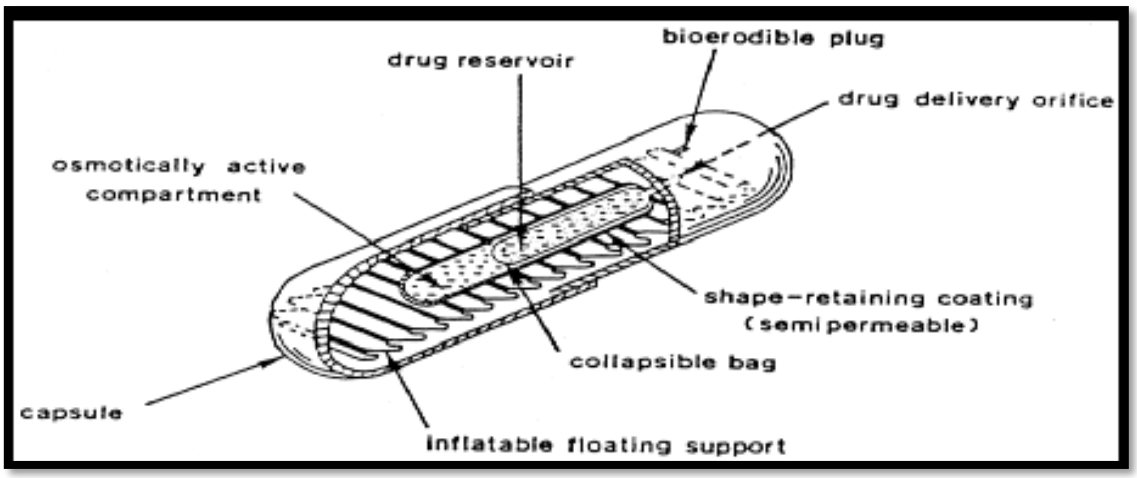


**Figure 11 : Intra- gastric osmotic controlled drug delivery system [34]**

**NON-EFFERVESCENT FDDS**

The mechanism of polymer swelling or bioadhesion to the GIT mucosal layer is the basis for the non-effervescent FDDS. Gelforming or highly swellable cellulose type hydrocolloids, polymethacrylate, polystyrene, and bioadhesive polymers like chitosan and carbopol are the most often utilized excipients in non-effervescent FDDS. In one method, after oral administration, gel-forming hydrocolloid swells in contact with gastric fluid while retaining its relative shape integrity and bulk density of less than unity in the gastric environment. The different kinds of this system are as follows:

**1. Single-layer floating tablets**

They are made by carefully combining the medication with a gel-forming hydrocolloid that maintains a bulk density of less than unity and expands when it comes into contact with gastric fluid. These dose forms are buoyant due to the air retained by the inflated polymer.

**2. Floating tablets with two layers**

A bilayer tablet has two layers: an immediate release layer that releases the first dose from the system, and a sustained release layer that absorbs gastric fluid and forms an impermeable colloidal gel barrier on its surface. The sustained release layer maintains a bulk density of less than unity, which keeps the tablet buoyant in the stomach.

**3. Alginate beads**

Freeze-dried calcium alginate was used to create multi-unit floating dosage forms. A sodium alginate solution can be dropped into an aqueous calcium chloride solution to create spherical beads with a diameter of about 2.5 mm. This precipitates calcium alginate and creates a porous system that can sustain a floating force for more than 12 hours

**4. Microspheres that are hollow**

A unique emulsion-solvent diffusion technique was used to create hollow microspheres, or microballoons, that were filled with medication inside their outer polymer shells. An agitated aqueous solution of PVA that was thermally regulated at 400C was filled with the drug's ethanol: dichloromethane solution and an enteric acrylic polymer. For almost 12 hours in vitro, the microballoons floated continuously across the surface of acidic dissolution fluid containing surfactant.

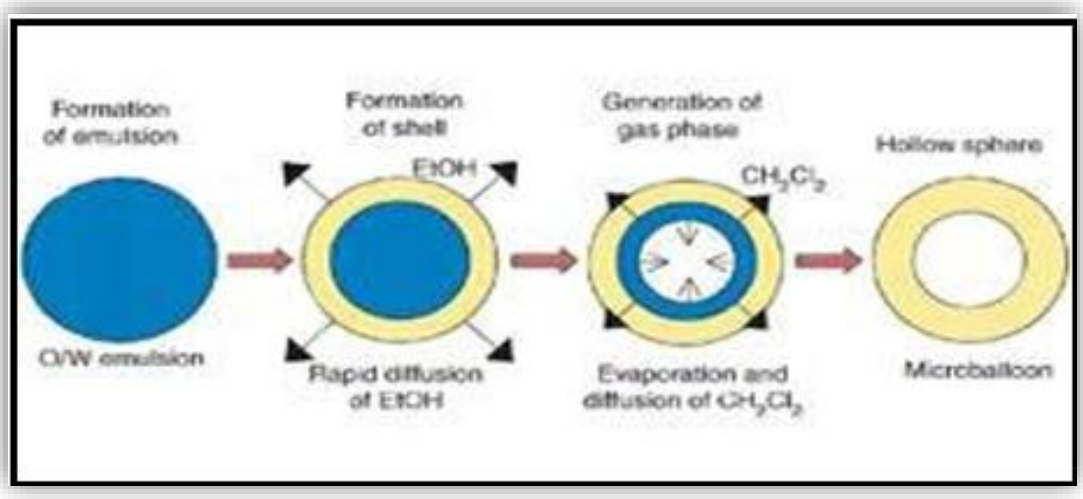


**Figure 12 : Formulation of hollow microspheres [37]**

**STOMACH-SPECIFIC FLOATING DRUG DELIVERY SYSTEM EVALUATION PARAMETERS IN VITRO AND IN VIVO**

Pharmaceutical dosage formulations with gastric residency in vitro floating behavior display prolonged stomach residence in vivo, according to several research published in the literature.

**PRECOMPRESSION DETAILS**

**1. Bulk density**

It is the mass of powder divided by bulk volume. Particle cohesion, shape, and size distribution all affect bulk density.

**Bulk density = M/Vo**

Where,

M = mass of the powder,

Vo = bulk volume of the powder

**2.Density of tapping**

A dry, clean 100 ml measuring cylinder was filled with 10 grams of powder. After that, the cylinder was tapped 100 times from a fixed height, and the volume that was tapped was recorded. It is provided by and stated in gm/ml.

**Tapped density = M/Vt**

Where,

M = mass of the powder,

Vt = final tapping volume of the powder

**3.The compressibility index**

Also known as Carr's index, is a crucial metric for figuring out how the powder flows. It has an indirect relationship with cohesiveness, particle size, and the relative flow property rate. It is a straightforward, quick, and widely used technique for forecasting flow characteristics. It is possible to represent Carr's index.

**4.Hausner'sratio :**

It is the ratio of tapped density to bulk density. It is given by

**Hausner ratio = Tapped density / Bulk density**

**Table no.1 Powder flow Characteristics in relation to Carr's index & Hausner's ratio**

| Compressibility Index (%) | Flow Characteristics | Hausner's ratio |
|---|---|---|
| <10 | Excellent | 1.00-1.11 |
| 11-15 | Good | 1.12-1.18 |
| 16-20 | Fair | 1.19-1.25 |
| 21-25 | Passable | 1.26-1.34 |
| 26-31 | Poor | 1.35-1.45 |
| 32-37 | Very Poor | 1.46-1.59 |
| >38 | Extremely Poor | >1.60 |

**5.Angle of Repose**

It is described as the greatest angle that can exist between the horizontal plane and the powder pile's surface. The fixed funnel approach was applied. A graph paper was laid on a flat horizontal surface, and a funnel was fastened with its tip at a specific height, "h." A funnel was carefully filled with powder until the conical pile's top just touched the funnel's tip. The following formula was then used to get the angle of repose.

$$\text{Angle of repose } (\theta) = \tan^{-1}(h/r)$$

Where, h=height of the pile,

r=radius of the pile,

θ=angle of repose.

**Table no.2 Powder flow characteristics in relation to Angle of repose**

| Sr.No | Angle of Repose | Powder Flow Characteristics |
|---|---|---|
| 1 | <25 | Excellent |
| 2 | 25-30 | Good |
| 3 | 30-40 | Passable |
| 4 | >40 | Very Poor |

**6. Drug-excipient (DE) interactions: [38, 39]**

FTIR is used for this. The DE interaction is indicated by the emergence of a new peak and/or the loss of the original drug or excipient peak. In addition to the evaluation criteria listed above, the impact of aging can be assessed using hot stage polarizing microscopy or a differential scanning calorimeter.

**PARAMETERS AFTER COMPRESSION**

**Tablets' thickness, hardness, friability, assay, and content uniformity:**

These tests can be carried out in accordance with the protocols specified in the official monographs. density of tablets [40] For floating tablets, tablet density is a crucial factor. Only when the tablet's density is lower than that of stomach fluid (1.004) will it float. The following relationship is used to calculate the density.

V = r2 h d = m/v

v = volume of tablet (cc),

r = radius of tablet (cm)

h = crown thickness of tablet (g/cc) and

m= mass of tablet Weight variation

Twenty pills were weighed both individually and collectively on a digital weighing balance in order to examine weight variance. The total weight was used to calculate the average weight of a single tablet.

**Table no.3 Tablet weights and the deviation permissible**

| Sr.No | Average weight of Tablet (As per USP) | Percentage Deviation | Average weight of Tablet (As per IP) |
|---|---|---|---|
| 1 | 130 mg or Less | ±10 | 80 mg or less |
| 2 | > 130 mg or < 324 mg | ± 7.5 | >80mg and <250mg |
| 3 | 324 mg or More | ± 5 | 250 mg or more |

**Calculating Total Floating Time and Floating Lag Time [41]**

Floating lag time is the amount of time that passes between the tablet's entry into the medium and its ascent to the upper third of the dissolving vessel; floating, flotation time, or total floating time is the amount of time that the dosage form floats. These tests are typically conducted using USP dissolving equipment as the dissolve medium in either 0.1 N HCl (900 ml) or Simulated Gastric Fluid (SGF) kept at 37 °C. Tablet swelling indices [26] Tablets are weighed (W1) and put in a glass beaker with 200 mL of 0.1 N HCl that is kept at 37 ± 0.5° C in a water bath. The tablets were taken out at regular intervals, and a filter paper was used to carefully remove any extra surface liquid. After that, the enlarged tablets are weighed again (W2). The following formula is used to determine the swelling index (SI):

$$SI = ( W2 – W1 / W1)$$

Where,

W2 = Final Weight ,

W1 = Initial Weight

**In vitro drug release investigation [22]**

In vitro drug release tests are often conducted in intestinal and stomach fluids that are kept at 370 degrees Celsius. The USP dissolving apparatus is used to conduct dissolution testing. Samples are taken out of the dissolution medium on a regular basis, replaced with the same volume of new medium each time, and their drug contents are then determined after the proper dilution. Recent methodology as described in USP XXIII states that the dosage unit is allowed to sink to the bottom of the vessel before rotation of blade is started. The dosage units that would ordinarily float may be linked to a tiny, loose piece of non-reactive material, such as a few twists of wire helix. However, it has been demonstrated that typical dissolve techniques based on the British Pharmacopoeia (BP) or USP are inadequate indicators of in vitro performance for floating dosage forms.

**Micromeritics studies, surface characterization, drug loading, drug entrapment efficiency, particle size analysis, and percentage yield (for floating microspheres and beads) [43, 44].**

To measure drug loading, precisely weighed samples of beads or microspheres are crushed in a mortar and introduced to the proper dissolution media. The mixture is then centrifuged, filtered, and subjected to a variety of analytical techniques, including spectrophotometry. The amount of drug in the sample divided by the weight of all the beads or microspheres yields the percentage drug loading. The optical microscopy approach is used to determine the size distribution and particle size of beads or microspheres in the dry state. Scanning electron microscopy (SEM) is used to characterize the surface's exterior and cross-sectional morphology. The overall percentage yield of floating microspheres was calculated by dividing the measured weight of the prepared microspheres by the total amount of all non-volatile components employed in the microsphere preparation process.

**Gaining weight and absorbing water [45]**

The swelling characteristic of the floating dose form can be used to study weight gain or water absorption (WU). The dosage form is submerged in simulated gastric fluid at 37 °C for the duration of the study. Dimensional changes, such as tablet diameter and/or thickness, are measured at regular intervals of one hour until 24 hours have passed. The tablets are then taken out of the beaker, and any excess surface liquid is carefully removed with paper. After the swelled tablets were weighed again, WU was calculated as a percentage of weight growth using the formula,

$$WU = (Wt – Wo) X 100 / Wo$$

where Wt and Wo represent the dosage form's initial and time t weights, respectively.

**Gamma and X-ray scintigraphy [46,47]**

X-ray/gamma scintigraphy is the primary assessment metric for floating dose forms in in vivo investigations. In every experiment, the animals are given free access to water while fasting for the whole night. A radiograph is taken right

before the floating tablet is administered to make sure there is no radio-opaque material present. Because a radio-opaque substance is included, the dose form can be seen by X-ray. After ingesting the formulation naturally, 50 milliliters of water are added. Each animal undergoes radiographic imaging while standing, and the distance between the animal and the X-ray source should remain consistent during the imaging process to allow for easy detection of tablet movement. An X-ray machine was used to perform gastric radiography at 30-minute intervals for five hours. By carefully introducing a suitable short-lived gamma-emitting radioisotope, gamma scintigraphy allows for the non-invasive imaging of a dosage form's passage through its targeted site of delivery in vivo. A γ-camera or scintiscanner can be used for indirect exterior observation when a formulation has a γ-emitting radio nucleide. However, the primary disadvantages of γ-scintigraphy are the related ionizing radiation for the patient, the limited topographic information, the technique's intrinsic low resolution, and the costly and complex radiopharmaceutical preparation.

**Pharmacokinetic Research [48]**

AUC (Area under Curve), Cmax, and time to reach maximum plasma concentration (Tmax) were calculated using a computer in pharmacokinetic investigations. A Student t test was used for statistical analysis, with $p = 0.05$ serving as the minimal level of significance.

**FDDS APPLICATION [22,49]**

Due to the limited absorption window in the upper gastrointestinal tract, floating drug delivery provides a number of uses for medications with low bioavailability. It increases the bioavailability by keeping the dose form at the site of absorption. These can be summed up as follows.

**1.Long-term medication administration**

Because the HBS system may stay in the stomach for extended periods of time, the medication can be released gradually. These technologies can thereby solve the issue of short gastric residence time that arises with an oral controlled release formulation. These systems can float on the stomach contents since their bulk density is less than 1.

**2. Drug delivery that is site-specific**

These systems are especially beneficial for medications that are selectively absorbed from the stomach or the proximal portion of the small intestine, such as misoprostal, furosemide, and riboflavin.

**3.Enhancement of absorption**

In order to maximize absorption, drugs with limited bioavailability due to site-specific absorption from the upper part of the gastrointestinal tract may be developed as floating drug delivery devices. Increased BioavailabilityWhen riboflavin CR-GRDF is administered instead of non-GRDF CR polymeric formulations, its bioavailability is greatly increased. The amount of medication absorption is influenced by a number of interrelated mechanisms that are connected to the drug's transit and absorption in the gastrointestinal system.

**4.Reduced Adverse Colon Activity**

The amount of medication that reaches the colon is reduced when it is retained in the stomach's HBS systems. As a result, the drug's unwanted effects in the colon may be avoided. The GRDF formulation for betalactam antibiotics, which are only absorbed from the small intestine and whose presence in the colon causes microorganisms to acquire resistance, is justified by this pharmacodynamic aspect.

**5. Decreased Drug Concentration Fluctuations:**

Compared to immediate release dosage forms, continuous drug input after CRGRDF treatment results in blood drug concentrations within a smaller range. As a result, concentration-dependent side effects linked to peak concentrations can be avoided and drug effect fluctuations are reduced. For medications with a limited therapeutic index, this characteristic is especially crucial.

**FDDS ADVANTAGES [50,51]**

For medications that are absorbed through the stomach, the FDDS is beneficial. For instance, antacids, ferrous salts, and medications intended for local action in the stomach benefit from the FDDS. Antacids, for instance. Aspirin and other acidic compounds irritate the stomach wall when they come into touch with it. Therefore, aspirin and other comparable medications may be administered using the HBS formulation. Poor absorption is anticipated when there is a strong bowel movement and a brief transit period, as may happen with some types of diarrhea. In certain situations, it could be beneficial to keep the medication floating in the stomach in order to achieve a comparatively better response.

**FDDS DISADVANTAGES [23]**

Numerous factors, including pH, food presence, and stomach motility, affect gastric retention. It is impossible to forecast buoyancy because these components are never constant. It is not appropriate to manufacture medications that irritate and damage the stomach mucosa as floating drug delivery systems. Due to its all-or-none emptying procedure, the gastric emptying time varies greatly. In supine patients, gastric emptying of floating forms might happen randomly and is heavily influenced by the size and diameter. Consequently, floating forms shouldn't be administered to patients right before bed.

**CONCLUSION**

The creation of an efficient gastro-retentive dose form for stomach-specific delivery of medicament. The floating drug administration technique turned out to be the most promising method of achieving the requisite gastro retention. Extending the stomach retention of the dosage form prolongs the time for drug absorption, which is a highly variable process in the gastrointestinal tract. FDDS appears to be a viable strategy for stomach retention. Many businesses are

concentrating on commercialising this approach, despite the fact that there are still many challenges to overcome in order to accomplish sustained stomach retention.

**References**


1. Hoffman A & Stepensky D, Pharmacodynamic aspects of modes of drug administration for optimization of drug therapy, Crit Rev Ther Drug Carrier Syst, 16 (1999) 571 639.
2. Hejazi R & Amiji M, Stomach-specific anti-H. pylori therapy. I: Preparation and characterization of tetracycline of a floating multiple-unit capsule, a high-density loaded chitosan microspheres, Int J Pharm, 235 (2002) 87-94.
3. Dave B S, Amin A F & Patel M, Gastroretentive drug delivery system of Ranitidine HCL formulation and in vitro evaluation, AAPS Pharm Sci Tech, 5 (2004) 1-10.
4. Sawicki W, Pharmacokinetics of verapamil and nor verapamil from controlled release floating pellets in humans, Eur J Pharm Biopharm, 53 (2002) 29-35.
5. Rubinstein A, Li V H K, Gruber P & Robinson J R, in Oral Sustained Release Formulations: Design and Evaluation, edited by A Yacobi & E Halperin-Walega (Pergamon Press, New York) 1988, 125-156.
6. Krogel I & Bodmeier R, Floating or pulsatile drug delivery systems based on coated effervescent cores, Int J Pharm, 187 (1999) 175-184.
7. Sheth P R & Tossounian J, The hydrodynamically balanced system (HBSE): A novel drug delivery system for oral use, Drug Dev Ind Pharm, 10 (1984) 313-339.
8. Ushimaru K, Nakamichi K & Saito H, Pharmaceutical preparations and a method of manufacturing them, US Pat 4, 702, 918, October 27, 1987.
9. Franz M R & Oth M P, Sustained release, bilayer buoyant dosage form, US Pat 5, 232, 704, August 3, 1993.
10. Desai S & Bolton S, A floating controlled-release drug delivery systems: in vitro–in vivo evaluation, Pharm Res, 10 (1993) 1321-1325.
11. Bolton S & Desai S, Floating sustained release therapeutic compositions, US Pat 4, 814, 179, March 21, 1989.
12. Dennis P, Timmins K & Lee S, Buoyant controlled release powder formulation, US Pat 5, 169, 638, December 8, 1992.
13. Mitra S B, Sustained release oral medicinal delivery device, US Pat 4, 451, 260, May 29, 1984.
14. Thanoo B C, Sunny M C & Jayakrishnan A, Oral sustained release drug delivery systems using polycarbonate microspheres capable of floating on the gastric fluid, J Pharm Pharmacol, 45 (1993) 21-24.
15. Kawashima Y, Niwa T, Takeuchi H., Hino T & Ito Y, Preparation of multiple unit hollow microspheres (microballoons) with acrylic resin containing tranilast and their drug release characteristics (in vitro) and floating behavior (in vivo), J Control Release, 16 (1991) 279-290.
16. Kawashima Y, Niwa T, Takeuchi H, Hino T & Ito Y, Hollow microspheres for use as a floating controlled drug delivery system in the stomach, J Pharm Sci, 81 (1992) 135-140.
17. Harrigan R M, Drug delivery device for preventing contact of undissolved drug with the stomach lining, US Pat 4, 055, 178, October 25, 1977.
18. Whitehead L, Fell J & Collett J H, Relevant of a gastroretentive dosage form, Eur J Pharm Sci, 4 (Suppl) (1996) S182.
19. Krogel I & Bodmeier R, Development of a multifunctional matrix drug delivery system surrounded by an impermeable cylinder, J Control Release, 61 (1999) 43-50.
20. Streubel A, Siepmann J & Bodmeier R, Floating matrix tablets based on low density foam powder: Effects of formulation and processing parameters on drug release, Eur J Pharm Sci, 18 (2003) 37-45.
21. Kumar S, Jamil F, Rajput M, Sharma S, “Gastro Retentive Drug Delivery System: Features and Facts”, International Journal of Research in Pharmaceutical and Biomedical Sciences. 2012,3(1) :125-136.
22. Bhardwaj V, Nirmala, SL, Harikumar, “Floating Drug Delivery System : A Review”, Pharmacophore. 2013,4(1) : 26-38.
23. Sharma N, Agarwal D, Gupta MK, Khinchi M, “A Comprehensive Review on Floating Drug Delivery System”, International Journal of Research in Pharmaceutical and Biomedical Sciences. 2011,2(2) : 428-441.
24. Tripathy KD. Essentials of medical pharmacology. 6th edition.New delhi: Jaypee brothers medical publishers (9) ltd; P. 539.
25. Bhardwaj L, Sharma KP, Malviya R, “A Short Review on Gastro Retentive Formulations for Stomach Specific Drug Delivery : Special Emphasis on Floating In situ Gel Systems”, African Journal of Basic & Applied Sciences. 2011,3(6) : 300-312.
26. Suryawanshi A, Hiremath SP, “Floating Drug Delivery System - A Review”, American Journal of Pharm Tech Research. 2012,2(1) : 138-153.
27. Yang L, Fassihi R, “Zero order release kinetics from self correcting floatable configuration drug delivery system”, J Pharm Sci.1996 ;85 : 170-173.
28. Deshpande AA, Shah NH, Rhodes CT, Malick W, “Development of a novel controlled release system for gastric retention”, Pharm Res.1997; 14 : 815-819.
29. Burns SJ, Attwood D, Barnwell SG, “Assement of a dissolution vessel designed for use with floating and erodible dosage forms”, Int J Pharm. 1998; 160:213-218.

30. Joseph NJ, Laxmi S, Jayakrishnan A, “A floating type oral dosage form for piroxicam based on hollow microspheres: in vitro and in vivo evaluation in rabbits”, J Control Release.2002; 79: 71-79.
31. Soppimath KS, Kulkarni AR, Rudzinski WE, Aminabhavi TM, “Microspheres as floating drug delivery system to increase the gastric residence of drug”, Drug Metab Rev. 2001; 33:149-160.
32. Singh BN, Kim KH, “Floating drug delivery systems: an approach to oral controlled drug delivery via gastric retention”, Journal of Controlled Release. 2000,63,pp- 235–259.
33. Pal P, Sharma V, Singh L, “A Review on Floating Type Gastroretentive Durg Delivery System”,IRJP. 2012,3(4).37-43
34. Chien YW, “Novel Drug Delivery Systems”, 2nd edition, Marcel Dekker, New York, 1992, pp. 139–196.
35. Desai S, “A novel floating controlled release drug delivery system based on a dried gel matrix”, M.S. thesis, St. John’s University, Jamaica, NY, 1984.
36. Ichikawa M, Watanabe S, Miyake Y, “A new multiple-unit oral floating dosage systems. I: Preparation and in vitro evaluation of floating and sustained-release characteristics”, J. Pharm. Sci.1991; 80 : 1062–1066.
37. Pandey A, Kumar G, Kothiyal P, Barshiliya Y, “A Review on current approaches in gastro retentive drug delivery system”, 2012; 2, 60-77.
38. Gupia P, Vermani K, Garg S, “Hydrogels from controlled release to pH-responsive drug delivery”, Drug Discov. Today. 2002; 10, 369-379.
39. Klausner EA, Lavy E, Friedman M, “Expandable gastroretentive dosage forms”, J Cont Rel. 2003: 90, 14-62.
40. Shah SH, Patel JK, Patel NV, “Stomach specific floating drug delivery system: a review”,Int J Pharm Tech , 2009, 1(3), 628-629.
41. Shayeda, Jagadeesh N, “Floating Drug Delivery Systems”, Int J Pharm Sci Nano, 2009, 3(2), 601.
42. Mostafavia A, Jaber E, Jaleh V, Neal MD, Mahboubeh R, “Development of a prolonged release gastroretentive tablet formulation of ciprofloxacin hydrochloride Pharmacokinetic characterization in healthy human volunteers”, International Journal of Pharmaceutics,2011,409, 128–136.
43. Srivastava AK, Ridhurkar DN, Wadhwa S, “Floating microspheres of cimetidine: formulation, Characterization and in vitro evaluation”, Acta Pharm,2005,55, 277–285.
44. Tanwar YS, Naruka PS, Ojha GR, “Development and evaluation of floating microspheres of verapamil hydrochloride”, Brazilian J of Pharm Sci,2007, 43, 529-534.
45. Gergogiannis YS, Rekkas DM, Dallos PP, Chailis NH, “Floating and swelling characteristics of various excipients used in controlled release technology”, Drug Dev Ind Pharm,1993, 19, 1061-1081.
46. Whitehead L, Collet JH, Fell JT, Sharma HL, Smith AM, “Floating dosage forms: an in vivo study demonstrating prolonged gastric retention”, J Control Release,1998,55, 3-12.
47. Hilton AK, Desai PB, “In vitro and in vivo evaluation of an oral sustained release floating dosage form of amoxicillin trihydrate”, Int J Pharm,1992, 86, 79-88.
48. Klausner EA, Lavy E, Stepensky D, “Furosemide pharmacokinetics and pharmaco dynamics following gastro retentive dosage form administration to healthy volunteers”, J Clin Pharmacol,2003, 43, 711-720.
49. Mayavanshi AV, Gajjar SS, “Floating drug delivery systems to increase gastric retention of drugs: A review”, RJPT. 2008, 1, 345-348.
50. Samyuktha RB, Vedha HBN, Brahma RA, Punitha S, Parimala D, Victor R, “The Recent Developments on Gastric Floating Drug Delivery Systems : An Overview”, Int. Journal of PharmTech Research,2010,2(1), pp 524-534.
51. Gopalakrishanan S, Chenthilnathan A, “Floating drug delivery systems: A review.” Journal of Pharmaceutical Science and Technology, 2011, 3, 548-554.