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Gastro-Retentive Floating *In Situ* Gelling Drug Delivery Systems: A Comprehensive Review

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ABSTRACT

Since oral drug delivery can exhibit reduced bioavailability, as they are pacified quickly in the gastrointestinal tract and poorly dissolved or maintained, the need to extend gastrointestinal residence exists. This paper assesses the floating *in situ* gelling systems to improve retention, controlled release and bioavailability. It discusses the gastro-retentive methods with respect to *in situ* gels and floating systems. Physiological triggers (pH, temperature), physical reactions (swelling, solvent transport) and chemical reactions (ionic cross-linking, enzymatic reactions, photopolymerization) are known as mechanisms. Key ingredients are polymers that include gellan gum, pectin, alginate, chitosan, cellulose derivatives, poloxamers and poloxamines. Testing involves buoyancy, gelation, release of drugs, water absorption, and rheology. These systems are known to extend the length of residence of the gastric contents, maintain the release of drugs, dose scheduling, and compliance particularly to drugs which impact on the upper GI tract. All in all, floating *in situ* gelling systems present a promising platform, but it needs to be optimized and researched more in clinical settings.

Keywords: Floating *in situ* gel, *In situ* gelation, Gastroesophageal reflux disease (GERD), Dysphagia-friendly drug delivery, pH-triggered gelation.

1. INTRODUCTION

FDDS (Floating Drug Delivery System) is a method of delivering drugs that enhances bioavailability through an increase in residence time in the stomach.[1] It has been popular as a source of prolonged retention of gastric contents due to its low density since its introduction in 1968.[2] FDDS are also offered in the form of tablets, capsules, microspheres, films and microbeads. One recent technology is *in situ* gelling systems, which can deliver drugs orally, nasally, orally, intravenously and rectally, as well as the vagina.[1] *In situ* gelling systems are painless to swallow and enhance convenience particularly to dysphagia patients. The release of the drug is regulated because the system is not buoyed and does not influence the gastric emptying. It favours medicines, which are unstable in the bowel or are absorbed in the upper stomach, and drugs, which require local effect. Controlled release is guaranteed by a gel barrier that is created by polymers such as polysaccharides, polymethacrylates, hydrocolloids and HPMC.

Longer drug action, better patient compliance, fewer doses, and more affordable formulation are just a few benefits of floating *in situ* gelling systems. These systems can remain buoyant for about 8–10 hours, ensuring sustained plasma drug concentration and minimizing fluctuations.[3] However, certain limitations exist, such as delayed floating in high-density systems and the possibility of premature gastric emptying before buoyancy is achieved. Mechanisms like incorporation of low-density excipients or air entrapment are used to enhance floating, though they may also present challenges.[1]

2. Floating *in situ* gel

The constant and controlled flow of drugs, especially polymer based have gained interest over the past decades. *In situ* gelling systems are also promising as they are non-invasive to be used, require lower dosing and patients are also more inclined to be compliant. This is because of the physiological influence like pH, temperature or ionic change which makes them subjected to a sol-gel conversion.

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The residence time of a gastric gel is increased by oral *in situ* gels which form its low- density floating gel after its delivery has no consequences on gastric-duct emptying. This enhances bioavailability of drugs in the upper GI tract that are absorbed via controlled release and also so in local action. They can be conveniently administered in comparison with the tablets and capsules, in all dysphagic, elderly, and pediatric patients. Overall, the floating *in situ* gels are an effective cost-efficient, and easily administered systems to promote drug delivery.[21]

3. GRDDS

GRDDS are particular systems devised to stay longer in the stomach as compared to traditional dose compounds. This increased retention enhances drug solubility in the acidic environment, therapeutic concentrations and loss of drugs in the intestine. It also improves patient compliance, increasing the time interval between doses.

GRDDS offer regulated, slow delivery and lowered dosing routine as a result of enhanced dissolution and gastric staying. They provide superior gastric targeting and a higher concentration of drug at the gastric mucosa compared with nanoparticles, microspheres and liposomes. They can be used in the treatment of such conditions such as ulcers, gastritis, as well as, oesophagitis.

GRDDS can be used in antibiotics, antivirals, antifungals and H_2-receptor antagonists (e.g. cimetidine, ranitidine, famotidine), enhancing bioactivity, therapeutic performance and leading to less drug required, particularly those drugs with inferior intestinal stability or half-lives.[5,6]

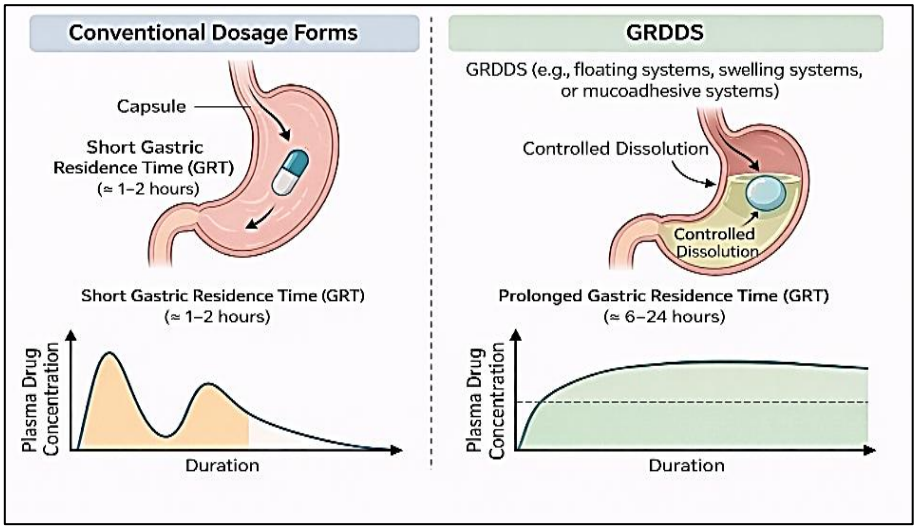

Figure 1. Structure of GRDDS

4. Floating drug delivery system (FDDS)

To improve the bioavailability and gastric retention of drugs absorbed in the stomach or at the upper small intestine, floating drug delivery systems (FDDS) have been developed. They float freely in gastric fluids without the influence on gastric emptying, thus enabling a prolonged and controlled release of drugs. After the release of drugs, the system leaves the stomach.

Long gastric retention enhances therapeutic efficacy and decreases changes in plasma concentration. Low-density materials or entrapment of air are used to gain buoyancy, and they can be multi or single-unit systems. Being a form of gastro-retentive system, FDDS lies on top of gastric contents, enhancing absorption of drugs in the upper gastrointestinal tract.[4]

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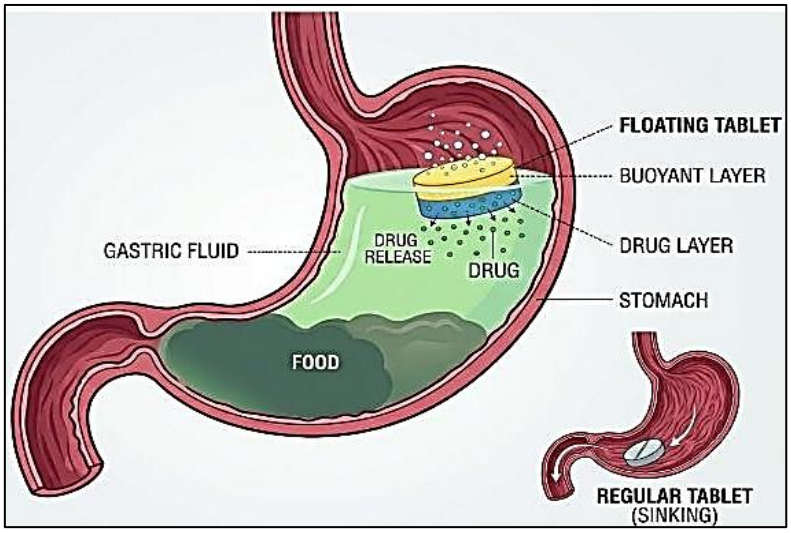

Figure 2. Structure of Floating Drug Delivery System

5. Floating drug delivery systems (FDDS) are needed.

The bioavailability of oral dosage forms may be low in case of quick gastric emptying, particularly in the case of drugs that are not very soluble in the alkaline intestinal environment. There is also rapid emptying of drugs that are targeted to produce localized gastric activity, resulting in a short residence time and frequent dosing. These limitations are overcome in floating drug delivery systems (FDDS), which enhance gastric retention.

Gastric-specific *in situ* raft or gel and stomach-specific *in situ* gel systems offer steady release coupled with higher retention. Stable, floating tablets and capsules are consumed without modification, but these have limited flexible dose, because they can be split, which can impact Both buoyancy and release.

Dose forms that are solid are not appropriate in patients with dysphagia particularly the elderly and children. *In situ* gels that are environment-responsive target gastrointestinal tissues and liquids follicles (gastric fluid) with fixed low-density form follicles, now known as a raft, where the transformed gastric fluid filaments the follicle and the follicle encases the drug.[13]

6. Advantages of *In situ* Gels[12,13]

- **Long-term and continuous medication release :** This minimizes the frequency of dosing while increasing therapeutic efficacy.
- **Increased adherence by patients :** Easy administration and fewer doses enhance convenience, especially in ophthalmic, nasal, and injectable systems.
- **Decreased systemic side effects :** Site specific administration reduces adverse effects and systemic exposure.
- **Enhanced bioavailability:** Improved drug absorption and retention at the target site increase bioavailability.
- **Non-invasive/minimally invasive delivery:** Enables needle-free, painless administration, particularly in ophthalmic and nasal routes.
- **Formulation flexibility:** Responsive to pH, temperature, and ionic strength**,** allowing customized drug delivery.

7. Disadvantages of *In situ* Gels[12,13]

- **Formulation complexity:** Achieving site-specific, timely gelation under physiological conditions is technically challenging.
- **Incomplete gelation risk:** Improper gel formation may cause drug leakage and unpredictable release**.**

- **Drug release variability:** Physiological and environmental variations affect gel formation and release profiles.
- **Limited drug loading:** Low drug loading capacity, especially for poorly soluble drugs, limits high-dose use.
- **Stability issues:** Possible stability and shelf-life limitations requiring controlled storage conditions.
- **Local irritation:** Certain excipients may cause irritation in sensitive tissues (ocular, nasal mucosa).

8. Need for the study

One of the problems facing the pharmaceutical industry is the identification of effective and acceptable treatment to patients. As an enhanced drug delivery system, *in situ* gel formulations seek to enhance therapeutic outcomes. Floating drug delivery systems maintain the drug in the stomach so they are applicable to poorly soluble or labile drugs in the intestinal fluids.

Floating *in situ* gels are kept buoyant because of low density in comparison to the gastric fluids. They have a higher bioavailability, longer drug release, and lower dosing frequency, as well as better patient compliance, than conventional dosage forms. Once given, the formulation is swelled in gastric fluid and constitutes a floating gel, which allows it to release sustainedly and increase its therapeutic effect.[4]

9. Mechanism of floating *in situ* gel [3]

Numerous methods can be used to prolong the residence time of gastrointestinal fluids through several mechanisms: floating systems (gas-forming, swelling/expandable), mucoadhesive systems, high-density formulations, shape-altered systems and the delay of gastric emptying by drugs. Floating dosage form are the most popular among them.

The floating drug delivery systems (FDDS) are not absorbed by the normal gastric emptying process because they are not absorbed by the lower density as they have been. They deliver regulated drug delivery, extended gastric retention, and stable plasma drug concentrations to complete drug delivery at which point the system is disposed of.

The presence of adequate gastric fluid and adequate floating force (F) is necessary to maintain good buoyancy, and this can be monitored with special equipment and measures the amount of force it needed to hold the dosage form submerged. An increase in positive floating force will have increased buoyancy and better performance of FDDS.

$$\mathbf{F = Fbuoyancy - Fgravity = (Df - Ds)\ gv}$$

Were,

F = the total vertical force,

Df = fluid density,

Ds = object density,

v = volume and

g = acceleration or gravity.

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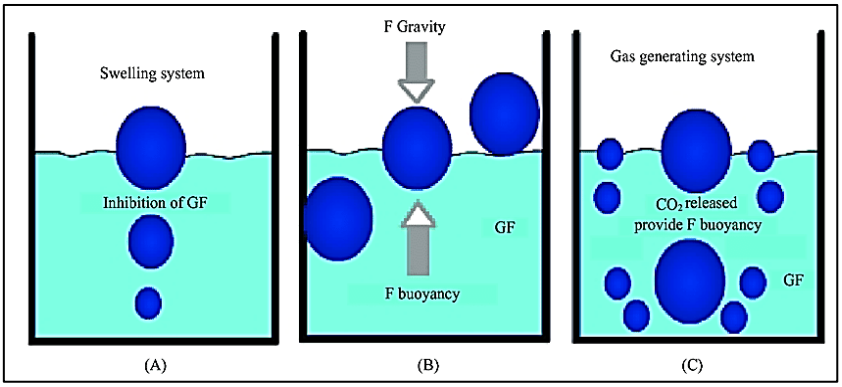
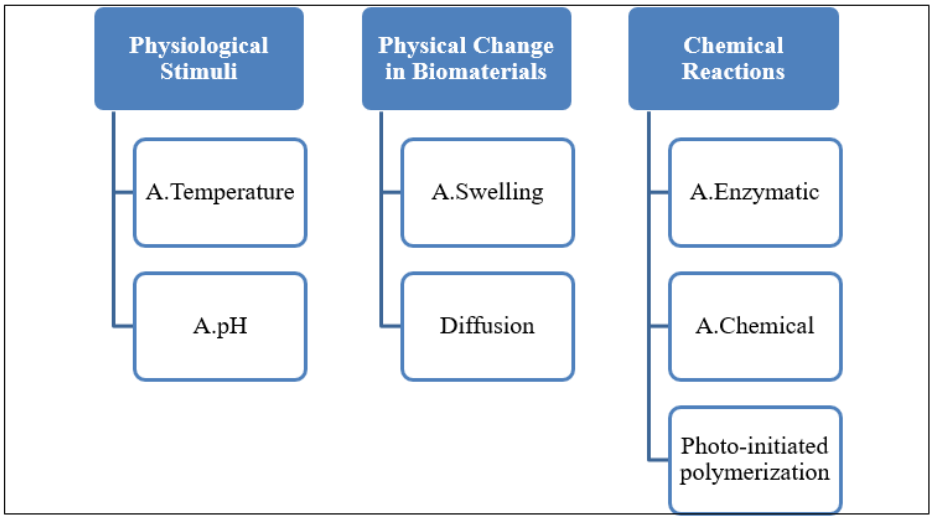


Figure 3. The floating systems mechanism[27]

The following are various methods and processes used or contributing to the production of the *in situ* gel:



9.1 *In situ* formation based on physiological stimuli:

A. Thermally triggered system

Environment-responsive Polymers are temperature-sensitive hydrogels which change between sol and gel in response to temperature changes. They normally gel within the body temperature and room temperature and so they can be administered and kept in gel state in response to slight variations.

The thermoreversible, positively thermosensitive, and negatively thermosensitive hydrogel are thermoresponsive. Polymers that exhibit a negative thermal sensitivity shrink at temperatures greater than LCST, whereas soluble solids such as PNIPAAm dissolve at lower temperatures and turn into hydrophobic at higher temperatures. Pluronics (PEOGoodwidden PEoPPOPEO) are popular thermoresponsive polymers which shape both micelles and gel at the temperature of the body. Positively thermal conduction gel is hydrogels that grow at temperatures that are hot and contract with lower temperatures.

Physiology Thermoreversible gels like the Pluronics, Tetronics and poloxamers are available at room temperature in liquid form and at physiological temperature in the gel form. The proteins are responsible to form irreversible gelation when injected into the protein-based systems, allowing weeks or months of controlled release of drugs in targeted delivery systems, such as ProLastin.

B. pH triggered systems

In situ gelation in response to pH is physiologically-induced. Polyelectrolyte Polyelectrolytes can be defined as ionizable polymers, which can react to the pH through proton exchange. At a high pH, anionic polymers swell whereas cationic polymers swell less. PAA polymer (such as Carbopol) is the basis of most anionic pH-sensitive polymers.

Poly(vinyl acetal diethyl amino acetate) (AEA) is neutral in nature and forms hydrogels at neutral pH that is low-viscosity at acidic pH (~pH 4). pH-responsive *in situ* gels were introduced to eliminate low bioavailability, and fast clearance of liquid formulations. PAA-based systems have the ability to gel at physiological pH (7.4) and can become irritating when used in high concentrations. PAA usage in combination with HPMC enhances performance because it is a liquid at pH 4 and forms a gel at pH 7.4. PGMAPEG blends can be also applied as efficient pH-sensitive *in situ* gels.

9.2 Physical mechanisms-based *in situ* gel formation

A. Swelling

In situ gels can also take the form of a mechanism of physical swelling, as the polymers are absorbed in water and then swell and file across the area of interest. For example, Myverol® 18-99 (glycerol mono-oleate) swells in water and forms lyotropic liquid crystalline phases. The adhesive use and enzymatic biodegradability of bacteria makes it applicable in drug delivery processes.

B. Diffusion

Solvency diffusion is another physical way of forming *in situ* gels in which the solvent is diffused into the tissue around the area, resulting in precipitation or solidification of the polymer at the location. It is commonly used as N-methyl-2-pyrrolidone (NMP), which effectively enhances the precipitation and the formation of the gel by the polymers.

9.3 Chemical reactions-based *in situ* gel formation

In situ gelation may also be caused by chemical processes at the site of administration. These are photo-initiated reactions, ionic cross-linking, enzymatic reactions and the precaution of inorganic solids using supersaturated ionic solutions.

A. Ionic cross-linkage

Many polysaccharides form gels with mono- or divalent cations, and ion-sensitive polymers undergo phase change when certain ions are present. Whereas ß-carrageenan creates elastic gels with Ca^{2+}, carrageenan forms stiff gels with K^{+}.
Gellan gum When Ca2+, Mg2+, K2+, and Na2+ are present, the anionic polysaccharide (Gelrite®) produces *in situ* gels. Alginic acid gels with divalent or polyvalent cations through ionic interactions with glucuronic acid blocks, while low-methoxyl pectins mostly gel with Ca2+.

B. Enzyme cross – linking

Creation of enzyme-catalyzed *in situ* gel is less investigated yet appears to have an edge over chemical and photochemical techniques in that, it can be carried out under physiological conditions with no toxic initiators or monomers. It has been employed to create stimulus responsive hydrogel to deliver insulin. The increase in blood glucose causes the swelling of cationic polymers of the pH-sensitive cationic polymer which contain immobilized insulin and glucose oxidase, and with this, permanent release of insulin is possible. The rate of gelation can be modulated by varying the enzyme concentration and the gel can be injected prior to gelation.

C. Photopolymerisation

Photopolymerisation is widely used for *in situ* biomaterial formation, where monomers or reactive macromers with a photoinitiator are injected and gel rapidly upon electromagnetic radiation. Acrylate-type functional groups are commonly used due to fast photopolymerisation. Long-wavelength UV or visible light is preferred, as short-wavelength UV has poor tissue penetration and biological toxicity. While visible-light systems use camphorquinone and ethyl eosin, UV systems use ketone initiators (such as 2,2-dimethoxy-2-phenylacetophenone). These systems could be long-term stable in vivo or break down chemically or enzymatically. After injection, *in situ* photocuring via fiber-optic cables forms a gel that provides sustained drug release, enabling rapid polymerisation at physiological temperature and effective implantation in complex-shaped sites.

10. Polymers

Polymers can be divided into groups based on where they came from or how they were gelled. *In situ* gelling systems can be divided into two categories according to their source:

10.1 Natural Polymers

Natural polymers can be derived from microorganisms, plants, or animals. They are frequently utilized in medication delivery systems and are biodegradable and biocompatible.

A. Gellan gum

B. Pectin

C. Xyloglucan

D. Sodium alginate

E. Xanthan gum

F. Chitosan

G. Karaya gum

H. Psyllium husk

A. Gellan Gum

An anionic heteropolysaccharide, gellan gum, which is a repeating unit of glucose, rhamnose and glucuronic acid, is a product of Sphingomonas elodea. Gelrite is deacetylated gellan gum that is acquired after having alkali treatment. On the presence of Ca 2+ ions, it is gelled through double-helix cross points. Cation complexation and hydrogen bonding maintain stability of the network, forming a three dimensional structure. Gellan gum can also be utilized in the food industry as a stabilizer and suspending agent.[15,16]

B. Pectin

Plants produce pectins, which are anionic polysaccharides mainly composed of α-(1-4)-D-galacturonic acid. Gels containing low-methoxy pectin (degree of esterification < 50%) and Ca2+ ions through ionic cross-linking and shows pH-dependent gelation in acidic settings (egg-box model). For drug delivery**,** Ca^{2+} ions are required to form mechanically stable gels**.** A key advantage of pectin is its water solubility, avoiding organic solvents. After oral administration**,** divalent cations in gastric fluid trigger sol-to-gel transition. Ca2+ is complexed with sodium citrate to preserve pre-administration fluidity. This complex is stable at neutral pH and dissociates in acidic stomach conditions, releasing Ca2+ and causing gelation. To guarantee formulation fluidity prior to dosage and quick stomach gelation, calcium-citrate concentrations are tuned.[5,17]

C. Xyloglucan

Tamarind seeds produce a 1,6-D-xylose-linked 1,4-D-glucan backbone polymer, Xyloglucan, which contains side chains of 1,2-D-galactose where some 1,6-D-xylose-linked polymer molecules place the 1,2-D-galactose molecules at the terminus. Naturally, it fails to gel, but with some enzymatic degradation of galactose by β-galactosidase, it can be allowed to form a temperature-sensitive reversible gelation based on chain association. The sol-gel transition is determined by the extent of removal of galactose with gelling normally taking place at the body temperature within minutes. It can be used to deliver oral drugs because of the *in situ* formed gel following administration in the form of an oral solution in a cooled form, which increases gastric retention. Its intraperitoneal, rectal and ophthalmic drug delivery has also been investigated.[5,17]

D. Sodium alginate

Alginic acid is a natural polysaccharide that is made up of 1,4-glycosidic-linked units of 1-D-mannuronic acid (M) and 1-L-guluronic acid (G). Alginate produces gels in the presence of metal ions like calcium, lead and copper by reacting with guluronic acid blocks. It is also possible to get gelled through reducing pH. Alginate based systems find extensive application in ocular delivery of drugs/polymer to increase pre-corneal residence time due to its high gelling and mucoadhesive properties. The application of sodium alginate to encapsulate biomolecules, such as proteins, peptides and drugs, is common.[18,19]

E. Xanthan gum

Xanthan gum is an extracellular polysaccharide, a high molecular weight with a molecular production of Xanthomonas campestris. It has a cellulose skeleton of β-D-glucose units, which have trisaccharide on the side chains forming a mannose and glucuronic structure. It is an anionic polymer due to the presence of pyruvate and glucuronic acid. Xanthan gum has both a broad pH stability range and dissolves at both hot and cold temperatures.[14,17]

F. Chitosan

Chitin is deacetylated in an alkaline solution to produce chitosan, the second most common polysaccharide after cellulose. This biodegradable, biocompatible, non-toxic, and thermosensitive cationic polymer is made up of N-acetyl-D-glucosamine and D-glucosamine units. It is insoluble at neutral or alkaline pH and functions as a polycationic weak basic (pKa 6.2-7.0). It exhibits high mucoadhesion due to its positive amino groups attaching to negative mucosal surfaces, as well as pH and temperature-triggered gelation via electrostatic and hydrophobic interactions. Chitosan is perfect for site-specific drug administration because of its antibacterial qualities, affordability, and bio adhesive qualities; granules or laminates prolong gastrointestinal transit time, while thicker barriers impede release.[20,14]

G. Karaya gum

A vegetal secretion from Sterculia trees, karaya gum is an acidic polymer that is high in galactose, rhamnose, and galacturonic acid. Being one of the least soluble plant gums, it quickly swells in water at low concentrations (~1%), forming incredibly viscous colloidal solutions. It swells because of acetyl groups in its composition.[20]

H. Psyllium husk

The dried seed coats of Plantago ovata are used to make psyllium husk, a swellable, biocompatible, inert, cheap, and abundant polymer. Seeds include 10-12% heteroxylan mucilage, 5-10% lipids (sterols, unsaturated fatty acids), 15-18% proteins, trace amounts of aucubin and alkaloids, and carbohydrates such as planteose trisaccharide. Its significant swelling and release-retardant properties make it excellent for gastroretentive medication delivery systems.[20]

10.2 Synthetic Polymers[26]

Synthetic polymers are chemically synthesized and offer controlled mechanical and physicochemical properties.

A. Polyacrylic acid (PAA)

B. HPMC (Hydroxypropyl Methylcellulose)

C. Cellulose acetate phthalate (CAP)

D. Methylcellulose (MC)

E. Poloxamers

F. Poloxamines

A. Cellulose Acetate Phthalate (CAP)

CAP, or cellulose acetate phthalate, a pseudo-latex, forms by dispersing pre-formed polymer in water sans organic solvents. It's pH-sensitive: free-flowing at acidic pH (~4.4) but coagulates at physiological pH (7.4).

This trait suits CAP and cross-linked pH-responsive polymers for sustained ocular drug delivery, extending residence time. CAP aids γ-scintigraphy for retention studies, enteric coatings, and ophthalmic uses like dry-eye therapy. Hydroxypropyl methylcellulose (HPMC) features β-(1→4)-D-glucopyranose chains; methylcellulose (MC) arises from methylating cellulose hydroxyls. Unlike most cellulose derivatives, both show thermoreversible gelation with rising temperature.[14]

B. HPMC

Hydroxypropyl methylcellulose (HPMC), a water-soluble cellulosic ether, excels in aqueous/organic solubility, flexibility, neutrality (no taste/Odor), and stability against heat, light, air, and moisture. HPMC solutions stay liquid at ~30°C but gel at 40–50°C.

Gelation stems from hydrophobic interactions among methoxy-substituted chains: low temperatures keep chains hydrated with weak links; heating dehydrates them, drops viscosity, then triggers strong polymer associations into a 3D network—marked by a sharp viscosity spike. *In situ* gelling drug delivery devices are powered by this sol–gel transition.[17]

C. Polyacrylic acid (PAA)

Polyacrylic acid (PAA), known commercially as Carbopol, boosts pre-corneal residence time in ophthalmic formulations. It offers superior mucoadhesion compared to typical cellulose-based polymers. Among Carbopol grades like 910, 934, 940, and 941, Carbopol 940 shows the best mucoadhesion and overall formulation performance.[14]

D. Methylcellulose (MC)

Methylcellulose (MC), a polymer produced from cellulose, functions as an *in situ* gelling agent with thermoreversible sol–gel transitions in aqueous solutions at between 40 and 50°C (MC) or around 75 and 90°C (HPMC); these can be decreased through blending or chemical adjustments. Gelation arises from hydrophobic interactions of methoxy-substituted chains: low temperatures keep polymers hydrated with loose entanglements; heating dehydrates them, cuts viscosity, then sparks strong associations into a 3D network—yielding a sharp viscosity jump. Solutions stay liquid at ~30°C but gel at 40–50°C, enabling *in situ* gelling drug delivery systems.[14]

E. Poloxamers (Pluronics)

Poloxamers (Pluronics), thermosensitive PEO–PPO–PEO triblock copolymers, enable temperature-dependent gelation and extended drug residence in *in situ* systems.

Pluronic F127, the top grade with ~70% PEO and ~30% PPO, forms clear, transparent gels; gelation hinges on PEO/PPO ratio and molecular weight.

Solutions act as viscous liquids at ~25°C but undergo sol–gel transition at ~37°C: micelles grow, pack tightly, and form networks on heating, spiking viscosity. Poloxamers serve as gelling agents, emulsifiers, and solubilizers.[14,17]

F. Poloxamines (Tetronics)

Poloxamines (Tetronics) are biocompatible, tetra-functional PEO–PPO block copolymers with an X-shaped structure from four PEO–PPO chains linked by an ethylenediamine core. This architecture drives their unique osteoinductive properties, unlike other polymers. They form micelles and gels responsive to temperature and pH for dual-responsive systems. Hydrophilic variants offer higher cytocompatibility than hydrophobic ones, with biocompatibility rising alongside molecular weight.[14,17]

11. Evaluation

A. Physical Appearance

Prepared *in situ* gel formulations must be clear and particle-free. Sol-to-gel conversion time is measured by placing the formulation in pH 1.2 buffer, with gel nature and consistency assessed visually.[5]

B. Clarity

By visually observing the *in situ* gel solutions against both black and white backgrounds, any turbidity or suspended particles is detected.[9]

C. Drug content measurement.

A predefined quantity of the product is dissolved in a suitable solvent and agitated for a set interval of time. This quantity corresponds to a known dosage of the medicine. The analytical procedure outlined in the drug's official monograph is then used to filter the solution and determine its drug content. Based on the formulation's equivalent weight, the computation is performed.[23]

D. pH Determination:

The pH of the prepared solution is tested with a digital pH meter. The ideal pH parameters for in situ gel formation are found, and the effects of different pH values on the sol-to-gel transition are assessed by exposing the formulation to fluids with different pH levels.[23]

E. In-vitro Gelling Capacity

By creating a colored formulation that allows for visual inspection, the *in situ* gel-forming system's gelling capacity is assessed. Parameters including gelation time, gel stiffness, and the amount of time the created gel stays intact are measured after the formulation is put to a medium that mimics gastric fluid.

Based on stability and Gelling duration, the in vitro gelation capability is categorized into three types:

- (+) A few minutes later, gel forms and spreads rapidly.
- (++) Quick gelation; gel can last up to 12 hours.
- (+++) gelation that happens instantly and lasts longer than 12 hours.[9]

F. Studies on In-vitro Buoyancy

The in vitro buoyancy of the formulation is assessed by mixing a certain volume of the *in situ* gelling formulation with a media that resembles stomach fluid. The total floating time is the amount of time the produced gel remains buoyant on the surface; the floating lag time is the amount of time needed for the formulation to rise to the medium's surface.[23]

G. Study of In vitro Drug Release :

A USP (standard) dissolving device Type II (paddle method) running at 50 rpm is used to assess in vitro drug release. The investigation is carried out at 37 ± 0.5 °C in 900 mL of 0.1 N HCl (pH 1.2). A Petri plate containing 10 mL of the formulation is carefully placed within the dissolve vessel. The dissolving media is then added without altering the formulation. To maintain sink conditions, samples of the appropriate volume are removed at prearranged intervals and replaced with an equivalent volume of new dissolving media. It takes at least eight hours to finish the dissolution inquiry.[5]

H. Study of Water Uptake

The gel is carefully removed from the medium after the sol-to-gel conversion, and the liquid that has adhered to the surface is blotted using tissue or filter paper. It records the gel's starting weight. After that, the gel is submerged in the same medium or distilled water once more. It is then taken out every 30 minutes, blotted to remove any extra liquid, and weighed. To assess the gel's water uptake behavior, the weight gain brought on by water absorption is recorded at every interval. For *in situ* gelling floating formulations, the effects of pH and the concentration of gelling and cross-linking agents on viscosity, *in situ* gelation properties, buoyancy, and drug release can also be examined.[9]

I. Measurement of Rheological Properties of Sol and Gel

Using appropriate viscometers, such as a Brookfield viscometer or a cone-and-plate viscometer, the viscosity of the solution (liquid formulation) made with varying concentrations of gelling agents is evaluated. The viscosity of the gel is also measured to determine its strength and rheological behavior.[9]

J. Sol-Gel Transition Temperature and Gelling Time

The temperature at which the sol passes through a phase change to create a gel is known as the sol–gel transition temperature. The formulation is put in a sample tube and heated at a regulated rate to determine this. When the meniscus does not move when the tube is tilted, gel formation is verified. The time needed for the sol formulation to initially form gel under particular circumstances is referred to as the "gelling time".[25]

12. Conclusion

By effectively overcoming the drawbacks of traditional oral dose forms, floating *in situ* gelling drug delivery devices offer a novel and promising method of gastro-retentive drug delivery. Through buoyancy and *in situ* gel formation, these devices can extend gastric residence duration, allowing for regulated and prolonged drug release in the stomach, as the reviewed literature unequivocally shows. This approach is particularly effective for drugs that have little stability or solubility in intestinal fluids, have a short window of absorption in the upper gastrointestinal tract, or are intended to act locally in the stomach. The formulation's flexibility, which is enabled by the use of both natural and synthetic polymers, allows gelation in response to physiological cues including pH, temperature, and ionic strength. Evaluation tests verify that floating *in situ* gels have controlled drug release profiles, buoyancy, rheological characteristics, and desirable gelation behaviour, which ultimately lowers dosage frequency and increases patient compliance. The notion that floating *in situ* gelling systems can greatly improve oral bioavailability and medicinal efficacy is mostly supported by the results. However, to fully transform these systems into reliable and widely accepted pharmaceutical medications, more formulation optimization, in-vivo research, and clinical investigations are required.

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