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Review Article

A Review on Design and Application of Advanced Superporous Hydrogels in Gastro Retentive Drug Delivery System

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Abstract

Superporous hydrogels (SPHs) are a promising type of material for gastro-retentive drug delivery systems (GRDDS). They are attracting attention because of their ability to swell very quickly, their strong mechanical structure, and their long gastric retention. These hydrogels contain a network of interconnected pores that allows them to absorb a large amount of gastric fluid within minutes. As a result, they expand to many times larger than their original size. This rapid swelling helps them stay in the stomach by preventing their passage through the pylorus, which supports a longer residence time and controlled release of drugs at the required site. SPHs can be prepared from natural or synthetic polymers and often include cross-linking agents, gas-forming substances, and bioadhesive components to enhance their function. Their responsiveness to pH and mechanical stress makes them suitable for drugs that are absorbed in specific stomach regions, have poor solubility, or are unstable in the intestine. This review highlights methods of SPH preparation, important design factors, and drug-loading techniques. It also discusses their evaluation in laboratory studies (in vitro) for swelling, strength, and release performance. Despite encouraging results, several challenges remain, including large-scale production, differences in gastric motility, and concerns about polymer-related toxicity. Overall, SPHs hold significant potential to provide reliable, efficient, and patient-friendly options for oral drug delivery. With further research and improved formulation strategies, they may become a key platform for achieving safe and effective gastro-retentive therapies.

Keywords: Super Porous Hydrogels (SPHs), Rapid swelling, Porous structure, Gastric Retention

Introduction

Originally designed as a revolutionary drug delivery technology, super porous hydrogels (SPHs) essentially absorb and retain medications in the gastric media, allowing absorption in the stomach and upper gastrointestinal tract. While the pharmaceutical active component is being delivered, these systems swell in the stomach instantaneously and remain intact in the harsh environment of the stomach. Basic medications with short elimination half-lives and limited solubility at higher pH levels can have their bioavailability improved by using oral controlled drug delivery systems, which release pharmaceuticals from the systems in a predictable and repeatable manner. The inability to extend the retention period of oral formulations in the stomach and the proximal portion of the small intestine is a significant disadvantage. To increase the amount of time that medications remain in the stomach, numerous techniques have been devised. Mucoadhesive or bioadhesive systems, high density systems, magnetic systems, superporous hydrogels, raft forming systems, low-density systems, and floating ion exchange resins are some of the several dosage forms used to enhance the stomach residency.[1] Drugs can now be released at a steady pace for extended periods of time, ranging from days to years, thanks to recent developments in controlled release technology. For dosage forms intended for oral administration, the advantages of long-term delivery technology have not yet been completely realized. This is mostly because oral dose forms have a comparatively short gastrointestinal (GI) transit time 6–8 hours in humans.[2]

Hydrogel drug delivery system

Despite the fact that there are over 100 prescription medications, hydrogel drug delivery is most frequently utilized in the US market. Despite being a water-soluble polymer, this material exhibits gel characteristics when exposed to an aqueous environment. With varying degrees of replacements, HPMC is utilized in tablet form to delay the release of the medication for a longer period of time. Two aspects allow HPMC to operate as a regulated delivery system. First, because it contains hydroxyl propyl, it is hydrophilic. Second, because the HPMC chains are compacted in a tablet, they cannot dissolve quickly in an aqueous solution. These two

characteristics give the gelling qualities of a chemically cross-linked hydrogel. Despite the absence of chemical cross-linking in the HPMC structure, the pressure used to prepare the tablets provides sufficient entanglement and a barrier to allow for the delayed breakdown of the polymer.[3]

Gastro retentive drug delivery system

Oral administration is the most convenient and favoured method of delivering any medication to the body. The pharmaceutical industry has recently shown increasing interest in controlled release drug delivery via oral route, which has improved curing advantages like formulation flexibility, patient compliance, and convenience of dosage administration. Drugs with short half-lives are also those that are quickly eliminated from the bloodstream and readily absorbed from the gastrointestinal tract (GIT). Periodic medication dosing can produce appropriate curing action. These formulations aim to get over this restriction and keep the medication in the systemic circulation for a long time by releasing it gradually into the gastrointestinal tract (GIT) by oral sustained-controlled release. Such a medication would be kept in the stomach and released in a regulated manner, allowing it to be taking continually. Providing the gastrointestinal tract's (GIT) absorption sites. In order to provide a site-specific oral controlled release dosage, it is preferable to extend the stomach residence period through drug delivery. Extended stomach retention improves the drug's solubility in a high pH environment and boosts bioavailability. Additionally, it decreases drug waste and lengthens the time of medication release. For local action in the upper portion of the small intestine, such as the treatment of peptic ulcers, a longer gastric retention time (GRT) in the stomach may be beneficial. By focusing on site-specific medication release in the upper gastrointestinal tract (GIT) for either local or systemic effects, this method prolongs gastric residence time. The gastric retention time (GRT) is prolonged for longer periods of time by gastroretentive dose formulations. In the past, several gastro retentive drug delivery approaches were designed and developed, including: high density (sinking) systems that is retained in the bottom of the stomach, low density (floating) systems that causes buoyancy in gastric fluid.[4]

Gastric empty time

Food digestion and chyme delivery to the intestine for absorption are two of the stomach's primary jobs. Cycles of stomach contractions or muscular activity lead to gastric emptying. These stomach motor actions also lead to the gastric emptying of oral dose forms. Therefore, it is necessary to construct gastric retention devices to overcome the stomach motility. Gastric emptying of meals is conveniently divided into gastric emptying of fluids, digestible solids, and indigestible solids because the kind of gastric contraction relies on the type of contents in the stomach.[5]

Phase I: It is the quiescent or resting phase, lasting approximately for 40 to 60 minutes. During this time, the stomach is largely inactive with almost no contractions, and only minimal gastric secretions are present. Solid dosage forms, especially large or undigested materials, tend to remain in the stomach during this phase.

Phase 2: After that comes phase II, which is characterized by sporadic, irregular contractions lasting 20 to 40 minutes. Small movements start to mix and transport the contents as gastric secretions rise. Larger solids are still present in this phase, but there is limited mobility of liquids and tiny particles. It is also called as pre burst phase.

Phase3: sometimes referred to as the "housekeeping" or "burst" phase, lasts for approximately five to ten minutes. It is distinguished by powerful, consistent peristaltic waves that move indigestible substances and undigested residues from the stomach into the duodenum. Since the majority of non-retentive solid dose forms are evacuated from the stomach during this vigorous muscle action, this phase is crucial.

Phase 4: Only a few minutes long, Phase IV is a transitional stage that gets the stomach ready to go back to its inactive Phase I state. On the other hand, the stomach enters the fed state upon ingestion, substituting continuous, non-cyclic contractions for the MMC cycle. Particularly when there are substantial or fatty meals present, these contractions considerably slow down the emptying of the stomach. As a result, substances may remain in the stomach for 3 to 6 hours or more, depending on the meal composition. This has major implications for drug absorption and delivery. For example, gastroretentive drug delivery systems—such as floating tablets or mucoadhesive formulations—are designed to stay in the stomach longer.[6]

Super porous hydrogel system

A super porous hydrogel is a three-dimensional network of hydrophilic polymers that because of their interconnecting tiny pores absorb a lot of water quickly. SPHs are a novel kind of hydrogel with a large number of extremely large pores, diffusion causes the swelling; instead, capillary wetness does. In order to prepare SPHs, specific components are added to monomer-diluted water, such as initiators, cross-linkers, foam stabilizers, foaming aids, and foaming agents. In addition to their quick swelling, super porous hydrogels offer excellent mechanical strength, resilience in the stomach's acidic environment, slipperiness, biodegradability, and biocompatibility because they absorb water through capillary force rather than simple absorption, they inflate entirely within minutes, regardless of their size. Composites of second-generation super porous hydrogels are created that have modest and rapid swelling. proportion and enhanced mechanical qualities, whereas third-generation super porous hydrogel hybrids have excellent elastic qualities The local action of medications in the stomach, such as antacids and antibiotics for bacterial ulcers or medications that must be absorbed mostly in the stomach, will benefit most from gastric retention devices.[7]

Principle behind superporous hydrogel on gastro retentive drug delivery system

SPHs are primarily retained in the stomach because to their rapid swelling characteristic. SPH's initial volume is contained in a tiny, easily swallowed capsule, but upon oral administration, it quickly expands to a huge size in the stomach fluid to stop it from emptying into the intestine. When the gastric contraction reaches the hydrogel, the gastric tissues pass over it. It can tolerate stomach contractions since it is elastic, slick, and strong mechanically. It also floats and releases medication in the upper portion of the GIT because of its low density. Following release, a medication gradually degrades in the stomach due to either mechanical force or chemical/enzymatic hydrolysis of the hydrogel's polymer chains .[8]

Advantages of superporous hydrogels

1. In superporous materials, no matter how big the dried super porous hydrogel is, it will be swelling in a minute.
2. It weighs more when it is swollen than when it is dried.
3. When swelling occurs, they exert a considerable expansion force.
4. These can also be utilized for non-pharmaceutical and non-biomedical applications. They can be made elastic to reduce their rupture.

Classification of superporous hydrogels

- First generation as conventional super porous hydrogels (CSPHs)
- Second generation as superporous hydrogel composites (SPHCs)
- Third generation as superporous hydrogel hybrids (SPHHs)

First generation as a conventional superporus hydrogels (CSPHs)

For the first time, Chen developed a highly porous hydrogel in 2000 that swelled quickly and had exceptional absorption properties. To create the standard superporous hydrogel, vinyl monomer was used. The most widely used monomers are those with high hydrophilicity, including sulfopropyl acrylate and acrylamide. Superior swelling properties may be exhibited by hydrophilic monomers, such as carboxyl or amide in acrylic acid and acrylamide, respectively, or by ionic monomers, such as carboxylate in sodium or potassium acrylate. Swelling SPHs are difficult to manipulate because of their reduced mechanical strength. These are brittle; the formulation cannot stay in the stomach for a long time, and the structure may easily collapse under low pressure. Thus, scientists created the second generation[9], as shown in figure 2.

Second generation as superporous hydrogels composites (SPHCs)

This particular type of super porous hydrogel contains a super disintegrant as a swellable filler. Traditional super porosity hydrogel was transformed into a second generation super porous hydrogel by Baek (2001). A continuous phase is mixed with the scattered phase. Crospovidone, Primojel, and AC-Di-Sol are composite materials used in the creation of SPHs. AC-Di-Sol possesses strong mechanical qualities and a considerable swelling capability. Acidifying polymer ionizable groups can improve the mechanical properties of SPHs, allowing them to endure the strain of gastric contractions during the gastric motility phase. The mechanical properties of hydrogel composites are improved by the composite agent. However, hydrogel composites with high porosity are nonetheless fragile and brittle. Superporous hydrogel hybrids (SPHHs) of the third generation. Using acrylamide, methylene bisacrylamide, and a crosslinker, Omidian created a superporous hydrogel hybrid in 2003. Superporous hydrogel hybrids have remarkably high mechanical or elastic characteristics. A pre-cross-linked matrix swelling component is incorporated into SPHHs, which differ from super porous hydrogel composites. Chitosan and pectin are examples of composite compounds that are water-soluble polymers. An example of an SPHH is the creation of a sodium alginate-based acrylamide-based superporous hydrogel, which is then crosslinked with alginate chains by calcium ions. Hydrogel hybrids that are elastic, water-saturated, and extremely porous can tolerate a variety of pressures, such as compression, stiffness, twisting, and bending. Table 1 compares the several generations of superporous hydrogel.[10] Hydrogel composites use a complex agent that is cross-linked using an initiator, cross absorbent hydrophilic polymer, and other constituents. SPH contains a dispersed phase integrated into a continuous phase matrix.[11]

Table 1: Comparison of all three generation of super porous hydrogel [12]

Parameters	CSPH	SPHC	SPHH
Texture during synthesis	Soft, sticky and less Flexible	Soft and less flexible	Soft and flexible
During ethanol dehydration	No immediate hardening	Hard and brittle	Hard
Swelling capacity	100-300 g g^{-1}	100-300 g g^{-1}	Upto about 50 g g^{-1}
Swelling rate	5-30 s	5-30 s	5 s to a few min
Mechanical strength	No mechanical strength	Resist up to 2 N cm^{-2}	Resist up to 20- 100 N cm^{-2}
After swelling	Completely transparent	Not completely transparent	Non- sticky creamish opaque

Third generation as superporous hydrogels hybrides (SPHHS)

The third generation of SPHs was created based on SPH hybrids. These are modified second-generation variants that are predicated on an integrated IPN structure. Even though the second-generation SPHs could produce a hydrogel with more strength, a much higher strength was thought to be required, especially for the gastric retention application. In the case of SPHHs, a water-soluble hybrid agent is added to SPH formulations. This sparked the creation of the third generation of SPHs, also known as SPHHs (superporous hydrogel hybrids), which have better mechanical qualities. Thus far, the primary, secondary, and tertiary methods have been revealed. An active substance is introduced during SPH synthesis and subsequently treated in the ion solutions after the SPH is synthesized conventionally. The secondary strategy can be used to create SPHs with strong mechanical strength, even if the first approach is best suited for creating SPHs with rubbery qualities.[13] The ion composition was discovered to be a helpful tool for better managing the swelling and mechanical characteristics, even though the mechanical properties of SPHs can be much improved following an ion treatment.[14] Any ion composition can be utilized to alter and adjust SPH properties, depending on the activity of the ion (especially sodium, calcium, aluminium, and iron). SPH hybrids are made using standard SPH formulas, but during the hydrogel creation process, a synthetic or natural water-soluble and ion gelling polymer is added.[15]

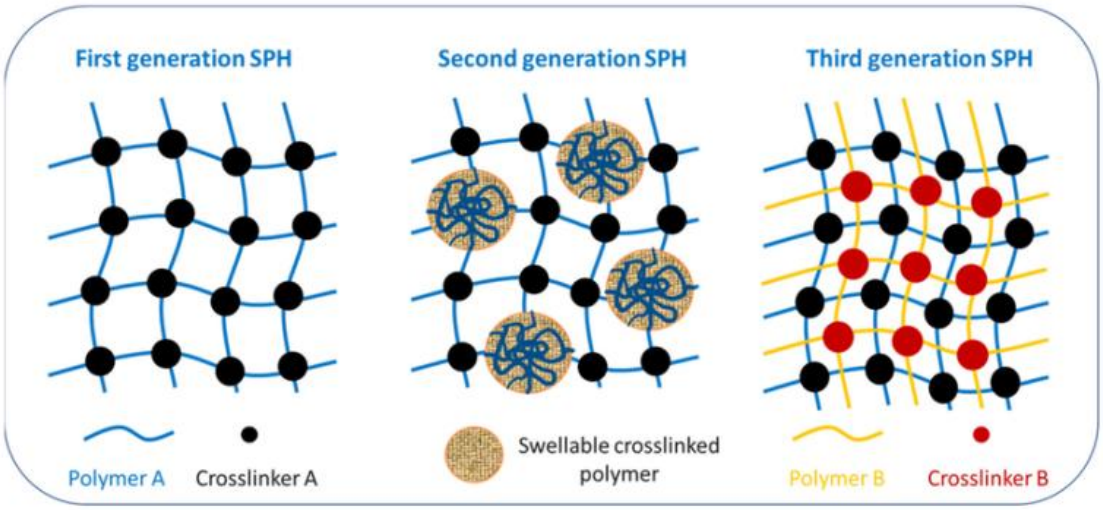

Figure 2: Superporous hydrogel generation

Method of Preparation

Preparation of gastroretentive superporous hydrogels involves four methods. They are

- Porosigen technique
- Cross linking technique
- Phase separation technique
- Gas blowing or foaming technique

Porosigen technique

Porous hydrogels are made using the porosigen technique while distributed, water-soluble porosigen is present. SPH is prepared using a variety of porosigens. They are 10 porosigen. The Porosigen Technique involves dispersing water-soluble porosigen to create porous hydrogels. SPH is prepared using a variety of porosigens. The nature of these porosigens is hydrophilic. The size of the porosigens determines the pore size that is generated in the hydrogel.[16]

Cross linking technique

These structures contain pores between the hydrogel particles. Pores are much smaller than particles in size. Cross-linked aggregates can be created by cross-linking individual hydrogel particles. This method is only applicable to hydrogel particles that have absorbent particles with chemically active pores in these structures. Pores are much smaller than particles in size. Cross-linked aggregates can be created by cross-linking individual hydrogel particles. Only absorbent particles with chemically active functional groups on their surface can use this method.[17]

Phase seperation technique

One of the most important steps in creating superporous hydrogel is phase separation. Monomers are typically combined with a diluent that benefits both monomers and polymers during solution polymerization. Furthermore, when phase separation is used to generate the gels, there is no control over their porosity.[18]

Gas blowing and foaming technique

In a test tube of a certain size, monomers, a cross-linking agent, foam stabilizer, and distilled water are first added. The pH is then adjusted to 5 to 6 using 5M NaOH. The creation of plastic foams from materials including polyurethanes, rubber, and poly (vinyl

chloride) has made extensive use of gas blowing technologies. A blowing agent, also known as a foaming agent, is the primary component of the foaming process. It is any material or mixture of materials that may create cellular structure in a polymer matrix. Superporous hydrogels undergo washing and drying following synthesis.[19]

Drug loading into superporous hydrogel

Drug is loaded into this superporous hydrogel delivery system by using any of two techniques.

- Drug loading into superporous hydrogel reservoir devices
- Drug loading into superporous hydrogel polymers

Drug loading into superporous hydrogel reservoir

The entire superporous hydrogel can serve as a reservoir for various medication delivery methods, such as microparticles or controlled-release tiny tablets.

Two types of drug delivery systems hass been designed

- Core inside shuttle system
- Core attached to surface of shuttle system

Core inside shuttle system

The core of this system is prepared as either gross mass or microparticles. The drug is dissolved in melted polymers, such as PEG 6000, to prepare microparticles, and the entire mixture is cooled to obtain gross mass. After being crushed and sieved, this gross mass is utilized as core material. Due to its high swelling ratio, SPH serves as the conveyor system's cap, while SPHC serves as the system's body due to its strong mechanical properties. Since the core must be integrated into SPHC, a hole is created inside the swelling SPHC using a borer. After that, the SPHC is dried at room temperature or at 60°C under decreased pressure. This is referred to as the conveyor's body, and it is covered by an SPH piece.

Core attached to surface of shuttle system

The main component of this system is a small tablet, which is made by dispersing the medication in melted polymer, such as PEG 6000, sieving it, mixing it with lubricant, and then compressing it into tablets using a single punch machine. The conveyor made up of only SPHC in which two holes were made on counter side instead of one as in previous approach. Cyanoacrylate, a bio-adhesive glue, was used to insert the core material (mini tablet) into the perforations. When the polymer comes into contact with stomach contents, it swells and the holes get bigger. The glue helps to keep the dosage forms at the site of drug absorption. The entire assembly is stored in size 000 gelatin capsule shells.

Drug loading into superporous hydrogel polymers

It is established how much water is needed for the hydrogel to fully swell. After that, a drug solution is made with a specified amount of water, and a weighed quantity of hydrogel is added to the drug solution to absorb it. The drug-loaded polymers that have fully swelled after 20 minutes are put in an oven set to 30°C to dry overnight.[20]

Drying of superporous hydrogels:

Superporous hydrogel is dried in two distinct ways. Swollen superporous hydrogel is dried under Condition I by being placed in an oven with warm air (60 °C) blown on it for a day. In Condition II, the swollen superporous hydrogel is first dehydrated using 5–10 ml of absolute ethanol. Following this first stage of dehydration, superporous hydrogels are repeatedly submerged in 50 milliliters of pure ethanol to further dry them and guarantee that the ethanol completely replaces the water. The soft, flexible superporous hydrogel changes into a rigid, brittle structure throughout the dehydration process. Following the completion of the dehydration process, paper towels are used to drain the excess ethanol from the dehydrated superporous hydrogel. After that, the superporous hydrogel is dried for a day at 55°C in an oven.[21]

Evaluation Parameter for Superporous Hydrogels

Swelling study

This is one of the key features of superporous hydrogel. By immersing the hydrogel in swelling media, the time it took for the hydrogel to reach equilibrium swelling was recorded ratio of swelling. The hydrogel was first allowed to completely dry before being stored in excess of the swelling medium [22]. The hydrogel was removed from the media and weighed at a prearranged time. The ratio of swelling was calculated as follows:

$$Qs = \frac{Ws - wd}{Wd} \times 100$$

Where,

Qs - Swelling ratio

Ws - Weight of hydrogel in swollen state

Wd - Weight of dried hydrogel.

Measurement of porosity

The solvent replacement method was employed to determine porosity. After blotting away excess ethanol from the surface, dried hydrogels were submerged in 100% ethanol for the entire night and weighed [23]. The following formula was used to determine the porosity:

$$Porosity = \frac{M1 - M2}{Vd}$$

Where

V is the hydrogel's volume

d is the density of absolute ethanol

M1 and M2 are the mass of the hydrogel before and after immersion in absolute ethanol.

Measurement of density of dried superporous hydrogels

The density (d) of the dried hydrogels was calculated by following equation:

$$d = \frac{WD}{VD}$$

Where Wd is the weight of dried hydrogel and Vd is its volume.Hexane was used as the displacement fluid in the solvent displacement method to calculate the hydrogel's volume. Because hexane is extremely hydrophobic and cannot be absorbed by superporous hydrogels, it was employed.[24]

Determination of gelation kinetic

The mixture's viscosity steadily rose during the gelation (polymerization reaction) process, leading to the formation of the entire network (gel) structure. After adjusting the pH to 5.0 using acetic acid, the gelation time—which was defined as the amount of time it took for the gel to form—was determined using a straightforward tilting technique. The time it took for the reactant mixture to stop descending in the tilted tube position was used as this parameter.[25]

Determination of void fraction

The following formula was used to determine the void fraction:

$$V = \frac{HDT}{TPV}$$

Whare V is Void Fraction and HDT is Hydrogel's Dimensional Volume and TPV is Total Pore Volume

Superporous hydrogels were submerged in a pH 1.2 HCl solution until equilibrium swelling was achieved in order to calculate the void fraction inside the hydrogels. Sample volumes were calculated as the dimensional volume using the measurements of the swollen hydrogels' dimensions. Meanwhile, the weight of dry hydrogel was subtracted from the weight of swelled hydrogel to calculate the quantity of absorbed buffer into the hydrogels. The resulting values were then used to calculate the hydrogels' total pore volume.[26]

Retention of water

The water retention capacity (WRt) as a function of time was calculated using the following formula:

$$WRt = \frac{Wp - Wd}{Ws - Wd}$$

Where Wp is the weight of the hydrogel at different exposure times, Wd is the weight of the dried hydrogel, and Ws is the weight of the completely swollen hydrogel. The water loss of the completely swelled polymer at predetermined intervals was measured using gravimetry in order to calculate the hydrogels' water-retention capacity as a function of exposure duration at 37 Oc.[27]

Mechanical property

A bench comparator is used to measure the penetration pressure (PP) of SPHs. The fully swelled hydrogel is placed lengthwise beneath the lower touch, and weights are progressively added to the top touch until the polymer ruptures completely.[28] The penetration pressure can be computed as follows, and the compressive force can be found using the measurement devices:

$$P = \frac{Fu}{s}$$

Fu is compressive strength at which the polymer breaks completely and S is Lower touch area.

Drug content determination

A 100 ml volumetric flask containing 4 mg of medication and a weight of superporous hydrogel was treated with around 10 ml of a pH 1.2 hydrochloric acid solution, well mixed, and topped up to volume. After filtering the mixture, the drug content was measured at 228 nm using a UV-Vis spectrophotometer.[29]

FT-IR Spectroscopy

FT-IR spectroscopy was utilized to determine the compatibility between the medication and the polymers. The chemical structure of the produced hydrogels was also examined using it. Using the KBr pellet approach, the Fourier-Transform Infrared (FT-IR) spectrophotometer (Shimadzu, FT-IR 8400S, Japan) captured the FTIR spectrum throughout the 400–4000 cm−1 range.[30]

Scanning electron microscopy [SEM]

To ascertain the morphology of the dried samples, scanning electron microscopy (SEM) investigations were conducted using the dried SPH. A Hummer Sputter Coater (Technics, Ltd.) was used to coat the samples with gold before they were examined under a JEOL JSM-840 scanning electron microscope (Jeol USA, Inc., Peabody, MA). Digital Scan Generator 1 (JEOL) and a digital capture card were used to take the pictures.[31]

In Vitro drug release study

Using a paddle technique United States Pharmacopoeia (USP) Dissolution Test Apparatus Type 2, the in vitro drug release of rosiglitazone maleate from the superporous hydrogels was assessed in triplicates at 37±0.5 0C for six hours at a rotation speed of 50 rpm in 900 ml of 0.1M HCl (pH 1.2). Ten milliliters of the dissolving medium were taken out at regular intervals, swapped out for an equivalent volume of brand-new dissolution fluid, and the drug was measured using a UV-Vis spectrophotometer (UV-1700, Shimadzu, Japan) set to 228nm several release models were fitted to the acquired data. The parameters n and k of the Korsmeyer-Peppas equation were calculated in order to ascertain the release mechanism.[32]

Application of Super Porous Hydrogels

SPHs were typically suggested as tools for stomach retention. But in the pharmaceutical and biological sectors, SPHs might be specially designed for functions other than stomach retention; these possible applications are also covered below.

1. Use to design gastric retention devices

Over the past few decades, numerous strategies have been developed based on tried-and-true ideas to stop the dose form from leaving the pylorus during stomach emptying. For the delivery of numerous medications, gastric retention devices may be quite helpful. These devices would be especially helpful for medications that are mostly absorbed in the stomach or that work locally in the stomach (such as antibiotics and antacids for bacterial ulcers). For medications with a limited window for absorption (i.e., mainly absorbed from the proximal small intestine), such as riboflavin, levodopa, p-aminobenzoic acid, a controlled release in the stomach would improve bioavailability. A gradual release from the stomach may increase bioavailability for medications that are quickly absorbed from the gastrointestinal system. Drugs that break down in the colon, such metoprolol, or that are poorly soluble in an alkaline pH medium can also be utilized using gastric retention devices. However, not all medications should result in prolonged stomach retention. For medications that are unstable at acidic pH, such as aspirin and non-steroidal anti-inflammatory medicines, gastric retention is undesirable. Furthermore, because the time spent in the colon can maintain blood levels for up to 24 hours longer stomach retention may not be required for medications that are largely absorbed in the colon.[33]

2. For design gastro retentive tablet

Gastro-retentive pills have been made by mixing and direct compression. Gelatin and tannic acid were combined with the SPH particles of acrylic acid/sulfopropyl acrylate copolymers, and the mixture was then tabulated by direct compression. Tannic acid, gelatin, and the carboxyl groups on the polymeric carrier form hydrogen bonds to form an integrated matrix that remains stable after swelling. Within 40 minutes, the gastro-retentive pill could expand up to 30 times its own volume without losing its original shape. It takes a compression force of up to 16 KPa for the enlarged pill to break. Carboxymethyl polysaccharides can be used in place of gelatin, depending on the pH of the swelling media.[34]

3. For design fast dissolving tablet

Oral administration of fast-dissolving tablets eliminates the need for swallowing and drinking. Children and the elderly particularly benefit from this feature. Fast-melting tablets are made by direct compression, sublimation, and freeze-drying. The first two techniques produce tablets that dissolve in 5–15 Ps, however the tablets lack mechanical strength and the process is relatively costly. Adding tiny SPH particles to the granulation or powder formulation is one approach of creating fast-dissolving tablets using the direct compression method. Through an enhanced wicking mechanism, the SPH microparticles inside the tablet core speed up water absorption. In less than ten seconds, tablets made by direct compression with SPH microparticles break down.[35]

4. As a super disintegrant

Superdisintegrants are pharmaceutically appropriate polymers designed for their swelling properties, such as cellulose, poly(vinylpyrrolidone), and starch derivatives. When added to a solid dosage formulation in the form of fine particles, SPH acts as a disintegrating agent. Because of its size and pore structure, the SPH superdisintegrant differs from traditional superdisintegrants in that it offers a substantially larger surface area.[36]

5. Protein peptide delivery system:

It has been investigated to use CSPH and SPHC for oral peptide delivery. This technology is intended to be administered directly to the designated location and physically adhere to the intestinal wall. By facilitating calcium extraction, the carboxyl-functionalized SPH opens closed junctions and neutralizes dangerous gastrointestinal enzymes. The goal of choosing the right enteric coating is to target a particular region of the colon or small intestine using this dosage form.[37]

6. Chemoembolization and occlusion devices

Chemoembolization is a technique that combines embolization and chemotherapy. By blocking the oxygen supply to malignancies that are spreading, embolization has been used to treat cancer. It is possible to achieve local delivery by reducing systemic toxicity. Chemotherapeutic and anti-angiogenic medications may be added to SPHs during chemoembolization therapy. The strong SPH improves occlusion and allows for better adaptation inside the blood vessel.[38]

7. Site-specific medication administration

This is especially advantageous for drugs like riboflavin and furosemide that are absorbed in the stomach or proximal small intestine. Misoprostol, a synthetic equivalent of prostaglandin E1 used to treat stomach ulcers brought on by NSAIDs, is delivered topically via a bilayer-floating capsule. Misoprostol is delivered to the stomach gradually, reducing medication waste and enabling the achievement of ideal therapeutic levels. Creation of Dietary Aid Meal replacement shakes, diet pills, diet soft drinks, and surgery have all been used to help people lose weight. Theoretically, the SPH's large and quick swelling capacity may take up a significant portion of the stomach, which would reduce appetite and meal capacity. It's possible that this gadget will help obese people lose weight.[39]

8. Future prospective of superporous hydrogels

In the field of pharmaceuticals, superporous hydrogels are becoming a major focus of research and development. Improvements could lead to improved mechanical, swelling, solubility, biocompatibility, and bioavailability as well as controlled porosity, enabling customization for certain biomedical applications. This technique is intended for use in dietary support, personalized medicine, artificial organs, prostheses, chemoembolization and occlusion devices, targeted drug delivery, oral peptide delivery, gastroretentive

dosage forms, superdisintegrants, and site-specific drug delivery.[40]

Conclusion

Superporous hydrogels (SPHs) have shown immense potential as advanced gastro-retentive drug delivery systems due to their rapid swelling ability, high porosity, mechanical strength, and strong gastric retention properties. By extending gastric residence time, SPHs enable controlled and site-specific drug release, thereby improving the bioavailability of drugs with short half-lives, poor solubility, or narrow absorption windows. The development of first-, second-, and third-generation SPHs has progressively enhanced their swelling behavior, elasticity, and mechanical stability, making them suitable for a wide range of pharmaceutical applications including gastro-retentive tablets, fast-dissolving formulations, peptide delivery, and chemoembolization devices. Despite their advantages, challenges such as polymer toxicity, variability in gastric motility, and large-scale production still need to be addressed. Future research should focus on optimizing polymer combinations, improving biocompatibility, and tailoring SPHs for personalized and targeted drug delivery. With continuous innovation, SPHs hold great promise in revolutionizing oral controlled release systems and achieving safer, more effective and patient-friendly therapies.

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