Review Article

A Conceptual Overview on Superporous Hydrogels

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ABSTRACT

Superporous hydrogels were originally developed as a novel drug delivery system to retain drugs in the gastric medium for those drugs having absorption window in stomach and upper part of the gastrointestinal tract. These systems should instantly swell in the stomach and maintain their integrity in the harsh stomach environment, while releasing the pharmaceutical active ingredient. For years, synthetic features and properties of these superporous hydrogel materials have been modified and improved to meet the requirements for gastric retention applications. Furthermore, an instant swelling hydrogel has also shown potential application for peroral intestinal peptide and protein absorption. This review discusses the formulation, techniques for synthesizing superporous hydrogel, different generations and drug loading techniques, characterization and properties. Synthesized superporous hydrogel and superporous hydrogels were characterized by Fourier-transform infrared spectroscopy, swelling kinetics, porosity, mechanical properties and scanning electron microscopy. Swelling of superporous hydrogel and superporous hydrogel composite was sensitive towards the ph, ionic strength, and temperature stimuli. The study of the surface morphology of superporous hydrogel using scanning electron microscopy showed a highly porous structure.

Keywords: Application, Hydrogels, Network structure of hydrogels, Superporous hydrogel, Swelling and Mechanical Properties.

INTRODUCTION

Hydrogels (also called aquagel) are cross linked hydrophilic polymers with a network structure consisting of acidic, basic, or neutral monomers which are imbibing considerable amounts of water sometimes found as a colloidal gel. Hydrogels are highly absorbent natural or synthetic polymers used widely in drug delivery, immobilization of enzymes, dewatering of protein solutions, solute separation, baby diapers, soil for agriculture and horticulture, water-blocking tapes, absorbent pads etc. Slow swelling is due to slow diffusion of water into glassy matrix of dried hydrogels. Sometime fast swelling polymer is more desirable; therefore, Chen et al., 1999 and Park developed a new kind of superabsorbent polymers so called superporous hydrogels. Swelling properties of hydrogels are mainly related to the elasticity of the network, presence of hydrophilic functional groups (-OH, -COOH, -CONH2, -SO3H) in polymer chains, extent of cross linking, and porosity. Hydrogels are divided into conventional hydrogels and new generation depends on their swelling characteristics. Hydrogel may be further classified into four; non-porous, micro-porous, macro-porous and super-porous hydrogels.[1-5]

Superporous hydrogel

In 1999, superporous hydrogels were introduced. Superporous hydrogels are a three-dimensional network of hydrophilic polymers that absorb a large amount of water in a very short period of time. These hydrogels are distinguished from other porous hydrogels in terms of their pore sizes and methods to generate the pores. Pores inside hydrogels are connected to form open channel system as capillary. Swelling of superporous hydrogels is done by capillary wetting rather than by diffusion. Thereby, Superporous hydrogels swell completely within minutes regardless of their size due to absorption of water by capillary force rather than by simple absorption. Second generation Superporous hydrogels composites are developed which shows fast swelling, medium swelling ratio and improved mechanical properties, while third generation superporous hydrogel hybrid possess high elastic properties. From present 13C NMR studies shows structure of superporous hydrogel consists of a sequence of acrylic acid (AA) and acrylamide (AM) as long aliphatic chains, which are cross-linked with N, N0 methylenebis acrylamide (Bis). Superporous structure induced by CO_2 formation then stabilized by cellulosic fibers (Ac- Di-Sol) which are responsible for a delayed but also complete swelling of these superporous hydrogel composites.[6-9]

Advantages of Superporous hydrogels

a. Swelling rate is very fast, within a minute regardless of its size.

b. Swells to such an extent that the weight of swollen state is higher than weights of dried State.

c. Having small percentage of solid content in total weight, it exerts significant expansion force during swelling.

d. It can be made elastic to minimize their rupture.

e. Superporous hydrogels can also be use for non-pharmaceutical and non-biomedical applications.[10]

Swelling and Mechanical Properties of Superporous Hydrogels

Swelling and mechanical properties are most important properties of superporous hydrogels. For gastric retention application swollen hydrogel with diameter larger than 15mm and mechanical resistance to pressure as low as 9–12.5 kPa is required. Superporous hydrogels shows high swelling ratio but low strength. A preparation method for producing super porouus hydrogel with both adequate swelling and mechanical strength is still lacking in the art.

Acrylamide-based Superporous hydrogels tend to be stronger but may not be acceptable pharmaceutically. Hydrogels based on poly(2-hydroxyethyl methacrylate) have low swelling ratio, But strong and durable with biomedical and pharmaceutical applications (implants, contact lens). Most common method to enhance hydrogel strength is to increase hydrogel crosslink, density and hydrophobic nature. Like addition of dimethacrylamide into an acrylamide based hydrogel. Increasing molecular weight can also enhance hydrogel modulus. Hydrogel annealing, multiple hydrogel systems (chitosan polyacrylic acid), grafting an anionic monomer onto a hydrogel substrate in aqueous medium of a cationic monomer, interpenetrating an amphoteric substrate with a nonionic synthetic monomer, cross linking of natural polymers with an aldehyde, and addition of clay are among some approaches to make a stronger high swelling hydrogel.

Mechanical properties including compression strength and elasticity of super-porous IPN hydrogels (SPIHs) improve up to 50 times as compared with superporous hydrogels. Super-porous IPN hydrogels were prepared by interpenetrating polymer network by incorporating a second polymer network inside a superporous hydrogel structure. Polyacrylonitrile was used as the second network. Combined chemical crosslinking and iontropic gelation, ion equilibration, freeze–thawing and drying, acidification as well as increased monomer concentration have all been attempted to enhance hydrogel strength.[11-15]

Network Structure of Hydrogels

Most important parameters that define structure and properties of swollen hydrogels are polymer volume fraction in swollen state, v2.s, effective molecular weight of polymer chain between cross-linking points, Mc, and correlation distance between two adjacent cross-links, ξ. Rubber-elasticity theory and equilibrium-swelling theory are extensively applied to describe these three dependent parameters.

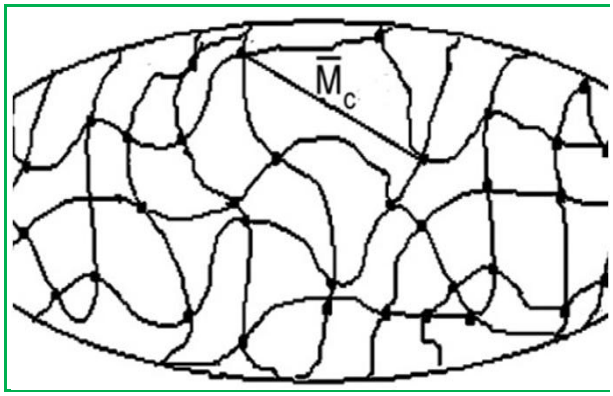

Figure 1: Schematic representation of cross-linked structure of a hydrogel[2]

Polymer volume fraction in the swollen state (v2.s) describes the amount of liquid that can be imbibed in hydrogels and is defined as a ratio of the polymer volume (Vp) to the swollen gel volume (Vg). It is also a reciprocal of the volumetric swollen ratio (Q) which can be related to the densities of the solvent (ρ1), polymer (ρ2) and the mass swollen ratio (Qm).

$$V_{2.S} = \frac{Vp}{Vg} = Q^{-1} = \frac{\frac{1}{\rho 1}}{\frac{QM}{\rho 1} + \frac{1}{\rho 2}}$$

The effective molecular weight of the polymer chain between cross-linking points is commonly related to the degree of cross-linking in the gel (X) as

$$X = \frac{M_0}{2\overline{Mc}}$$

Where, M_0 is an estimate of the molecular weight of the repeating units. Mc is the distance between sequential cross linking points, which represents an estimate of the available space between the macromolecular chains accessible for the drug diffusion. A study on L-18 Taguchi matrix showed, final properties of Polyacrylamide-based hydrogel networks as different concentrations showed definite effects on the gelation features of hydrogel formulations. Features, such as inhibition period, exothermic period and temperature rise, were found to be critically dependent on the type and concentrations of the materials within. Tough or very tough hydrogels were attainable under conditions that minimum inhibition and exothermic periods and maximum temperature rises (during gelation) are favored.[2,16]

GENERATION OF SUPERPOROUS HYDROGEL

First generation as conventional Superporous hydrogels

For the first time in 2000, Chen prepared superporous hydrogel with fast swelling and super absorptive properties. They used vinyl monomer. Most commonly used monomers are highly hydrophilic (acrylamide, sulfopropyl acrylate). During drying process porous structure of Superporous hydrogels become collapsed due to surface tension of water pulling polymer chains together and become hard and brittle. Sometime, water

inside Superporous hydrogels is replaced with alcohol (e.g. ethanol) which prevents porous structure from collapsing due to their low surface tension. Mechanical strength is major problem with conventional hydrogels. These are fragile and structure can easily break under low pressures. For this reason researchers developed second generation.[17-19]

Second generation as superporous hydrogel composite

In this type superporous hydrogel an extra material called superdisintegrant is added (swellable filler). These have good mechanical property withstands pressure up to 2N cm^2. Baek (2001) made modifications to conventional superporous hydrogel to form second generation superporous hydrogel by adding superdisintegrant. Composite material, which does not show any pharmacological effects but they enhance mechanical strength of hydrogels. Superporous hydrogel composite is a matrix of continuous phase having a dispersed phase incorporated within. A composite agent used in hydrogel composites is cross-linked water-absorbent hydrophilic polymer that can absorb solution of monomer, cross-linker, initiator and remaining components. Composite agent in hydrogel composites improves mechanical properties. But superporous hydrogel composites are still brittle and breakable.[6,20]

Third generation as superporous hydrogel hybrids

In 2003 Hossein Omidian prepared superporous hydrogel hybrid using acrylamide, methylene bisacryl amide as monomers and cross linker. They have very high mechanical or elastic properties. Unlike superporous hydrogel composites wherein a pre-cross-linked matrix-swelling additive is added, superporous hydrogel hybrids are prepared by adding a hybrid agent that can be cross-linked after superporous hydrogel formed. Hybrid agent is a water-soluble polymer (pectin, chitosan). An example of superporous hydrogel hybrids is synthesis of acrylamide-based superporous hydrogel in the presence of sodium alginate, followed by cross-linking of alginate chains by calcium ions. The resiliency of fully water-swollen Superporous hydrogels has never previously been observed. Elastic water-swollen superporous hydrogel hybrids can resist various types of stresses, including tension, compression, bending and twisting. They can withstand compression forces of up to 25 N cm^2.[6,17]

Stimuli sensitive superporous hydrogels

pH sensitive hydrogels

These are composed of polymeric backbone with ionic pendant groups. In aqueous media with appropriate pH and ionic strength pendant groups ionize to develop fixed charges on polymer network, generating electrostatic repulsive forces responsible for pH dependant swelling/deswelling of hydrogel thereby controlling the drug release (Mathiowitz 1999). Small change in pH can alter the pore size. Most commonly used ionic polymers poly (acrylamide), poly (acrylic acid), etc. Among natural polymers albumin (Park et al. 1998) and gelatin (Welz and Ofner 1992) have been studied. HEMA based pH sensitive polymeric network has been reported as self regulated device for insulin delivery (Klumb and Horbett 1992).[21]

Thermosensitive hydrogels

These hydrogels include various temperature sensitive polymers like N-substituted Acrylamide, methacrylamide. It has been reported that kinetics, duration and rate of drug release from hydrogels is affected by structural properties of the polymer such as degree of crystallization, size of crystallites, degree of swelling etc. Temperature sensitive polymers show a lower critical solution temperature (LCST) which induces hydration change of the polymer e.g. poly (n-isopropyl acrylamide) shows LCST of 34°C and 32°C for isopropyl amylburide hydrogels. Below critical solution temperature polymers are hydrated or soluble and swell to significantly higher degrees. This leads to shrinkage of network above LCST and decrease in network volume releasing the entrapped drug.[21]

Miscellaneous Superporous hydrogels

Development of Superporous hydrogels with mechanical properties identical applying different approaches, including acidification (using HCl), impregnation (using diallyldimethyl ammonium chloride or cationic polyethyleneimin), rubberization (adding rubber emulsions), surface crosslinking (using glycerin), bulk crosslinking thermogelation (using ovalbumine protein, egg white) and ionotropic gelation.[10]

Table 1: Ingredients for preparing superporous hydrogel[6]

Role	Example
Monomers	Acrylic Acid, Acrylamide, 3-Sulphopropyl acrylate potassium, Hydroxy ethyl methyl acrylate, N-isopropyl acrylamide, Acrylonitrile, Polyvinyl alcohol etc.
Cross linking agents	Chemical cross linker: Glutaraldehyde, N,N'-methylene bisacryl amide, formaldehyde. Ionotrpic cross linker: metal ions like calcium, iron and phosphorus.
Foam stabilizers	Pluronic F127, Pluronic P105, Silwet L7605, Span 80, Tween.
Polymerization initiator pairs	APS/TEMED(Ammonium persulfate/N,N,N,N tetramethyl ethylene diamine, Potassium per sulfate/Sodium metabisulfite, ammonium per sulfate/Sodium metabisulfite, Azo-initiator.
Foaming agents	Sodium bicarbonate, Sodium carbonate, Potassium bicarbonate.
Composite agents	Crosslinked sodium carboxy methylcellulose, Crosslinked Primojel and crospovidone, Carbopol, Polyvinyl alcohol.
Hybrid agents	Natural polymers: Sodium alginate, Sodium carboxymethylcellulose, Chitosan based on ionotropic gelation, Pectin. Synthetic polymers: Polyvinyl alcohol based on cryogelation.

Method of Preparation of Superporous Hydrogel

Porous hydrogels are prepared using freeze drying, porogenation microemulsion formation, phase separation foaming technique, emulsion-template synthesis, and particulate leaching.[18]

But superporous hydrogels are prepared by four methods explain below-

Gas blowing technique

This is most widely used. Initially monomers, cross linking agent, foam stabilizer and distilled water are added in a test tube of specific dimensions pH adjust 5 to 6 with 5M NaOH. Low pH favors polymerization reaction, later foaming agent is add to the reaction mixture which leads to formation of gas bubbles followed by increase pH of solution. Increasing pH accelerates polymerization process. During addition of foaming agent, polymerization initiator catalyst is added simultaneously. Both gellification and foaming reactions occurs simultaneously and which lead to entrapment gas bubbles in reaction mixture. After synthesis, Superporous hydrogels are subjected to washing, drying using different methods.[19,22]

Porosigen Technique

Porous hydrogels are prepared in presence of dispersed water soluble porosigen. Porosigens are hydrophilic in nature and come in contact with water to generate porous structure in hydrogel e.g. micronized (sucrose, lactose, cellulose), sodium chloride. Pore size generates in hydrogel depends on the size of porosigens.[21.22]

Phase separation technique

Phase separation is very critical process in generating superporous hydrogel because there is no much control over the porosity. So this method use in limited type of hydrogel prepared by HEMA (Hydroxy ethyl methyl acrylate) and NIPAM (N- isopropyl acrylamide).[19,21]

Cross linking technique

Crosslinking of individual hydrogel particles lead to aggregates of particles. Pores in such structures are present between hydrogel particles. Size of pores is much smaller than size of particles. This technique is limited to absorbent particles with chemically active functional groups on surface.[19,21]

Drug Loading Into Superporous Hydrogel Delivery System

Into superporous hydrogel reservoir devices

Superporous hydrogel can act as reservoir devices for drug delivery systems. There are two

- Core inside shuttle
- Core attached to surface of shuttle

Each shuttle systems are composed of two components core and conveyor. Core part contains drug blend and conveyor is made up with superporous hydrogel.[21,22]

Core inside the shuttle system

Core is prepared in two different forms micro particles and gross mass. Micro particles are prepare by dispersing drug in melted polymers like PEG 6000 and cool the mixture to get gross mass. This gross mass is crush and sieved through #400 µm for core material. Superporous hydrogel composite is use as body because of its greater mechanical strength and superporous hydrogel as cap of the conveyor because of its high swelling ratio. A hole is made inside superporous hydrogel composite in its swollen state by use of borer, as the core has to be incorporated inside superporous hydrogel composite. Superporous hydrogel composite is then dried by either at ambient temperature or by reduced pressure at 60°C.[21,22]

Core attached to surface of shuttle system

Core is in the form of small tablet prepared by dispersing drug in melted polymer like PEG 6000 and sieving mass through # 400 µm, add magnesium stearate and compressed into tablet to 40N hardness. Conveyor is made up with superporous hydrogel composite in which two holes are made on counter side. Core tablet is placed inside the hole using bio-adhesive (cyanoacrylate) glue. Polymer swells when comes in contact with gastric fluids and size of holes is enlarged. Glue helps to keep the dosage forms at the site of drug absorption. Same assembly is placed into gelatin capsule shells of size 000.[21,22]

Drug loading into superporous hydrogel

Amount of water required for complete swelling of specific weights of superporous hydrogel is determined. Then, aqueous solutions of given drug is prepared in pre determined amount of water and weighed amount of polymer is placed in drug solution to suck up the drug solution. After 20 min, polymers loaded with drug are placed in oven at 30°C for drying.[5,7,10]

Drying of Superporous Hydrogel

Swollen superporous hydrogel are dried under blowing warm air (60°C) in food dehydrator or superporous hydrogel are dehydrated first by applying about 5–10ml of absolute ethanol. After that they are further dehydrated using 50mL of absolute ethanol several time to ensure replacement of complete water. During this process, soft and flexible superporous hydrogel become hard and brittle. Excess ethanol is removed by draining using paper towel. Then superporous hydrogel are dried in oven at 55°C.[22]

EVALUATION OF SUPERPOROUS HYDROGELS

Scanning electron microscopy

SEM analysis is help to study morphology of a dried superporous hydrogel. Samples are coated with gold using Hummer sputter coater. Use Jeol JSM-840 scanning electron microscope to captured images using digital

capture card and Digital Scan Generator. This picture clearly indicates pores in its structure.[23-25]

Fourier transform infrared spectroscopy

In FTIR spectroscopy investigation of Superporous hydrogels, FTIR spectrum was recorded over the range of 400 - 4000 cm^{-1}. KBr pellet is a method of choice in which Transform Infrared FT-IR spectrophotometer are generally used.[5,23,24]

Measurement of Density

Direct density measurement of dried superporous hydrogel's volumes is difficult, Solvent displacement measurement method is used. Dried superporous hydrogel is treated with different solvents, which actually gives apparent densities of Superporous hydrogels. A piece of hydrogels is weighed for mass. With forceps, that piece is immersed in a predetermined volume hydrophobic solvent such as hexane that is not absorbed by superporous hydrogels in a graduated cylinder and measurement in the hexane volume is measured as volume of the polymer. Density is calculated from following equation

Density = M superporous hydrogel / V superporous hydrogel

Where, V superporous hydrogel is volume of solvent displaced by superporous hydrogel and M superporous hydrogel is mass of superporous hydrogel.[4,7]

Determination drug content

Superporous hydrogel required amount is taken in 100 ml volumetric flask. About 10 ml of buffer is added, mixed well and make up to volume. This mixture is filtered and drug content is determined using UV-Visible spectrophotometer at appropriate wavelength.[5,22]

Drug excipients compatibility

FT-IR spectroscopy is used. Prepared superporous hydrogel are subjected to FT-IR analysis by KBr pellet method using Fourier-Transform Infrared spectrophotometer and recorded over a range of 400-4000 cm^{-1}.[22]

Mechanical strength

Quantifying superporous hydrogel mechanical properties is challenging is measure by applying weight on swelled superporous hydrogel until it break. Mechanical strength is measure by using bench comparator and gastric simulator. A gastric simulator, based on the water-hammer theory, utilizes a controlled amount of different types of stresses on objects immersed in the testing fluid to simulate forces that a sample might receive upon ingestion in body.[5,6,25]

Determination of Void Fraction

Void fraction can be calculated by the following equation

Void Fraction = Dimensional volume of hydrogel / Total volume of pores

Void fraction is determined by immersing hydrogels in HCl solution (pH 1.2). Dimensions of swollen hydrogels are measured and by using these data, sample volumes are determined as dimensional volume. In the meantime, amount of absorbed buffer into hydrogels is determined by subtracting weight of dried hydrogel from weight of swollen hydrogel and resulting values are assigned as total volume of pores in hydrogels.[5,10]

Water Retention

Following equation is used to determine water retention capacity (WRt) as a function of time

WRt = (Wp – Wd) / (Ws – Wd)

Where, Wd is weight of dried hydrogel, Ws is weight of fully swollen hydrogel, and Wp is weight of hydrogel at various exposure times. Water loss of fully swollen polymer at timed intervals was determined by gravimetric at 37^{0}C.[10,23]

Porosity Measurement

Here solvent replacement method is used. Dried hydrogels are immersed overnight in absolute ethanol. It absorbed ethanol and swollen, which leaded to blotting of ethanol on the surface. Porosity is calculated from following equation

Porosity = (M – M1) / ρV

Where, M1 and M2 are mass of hydrogel before and after immersion in absolute ethanol, respectively; ρ is density of absolute ethanol and V is volume of hydrogel.[6,10]

Swelling property

Superporous hydrogels are characterized by their swelling and mechanical properties. Most important factors are ionic strength, pH, salts, organic solvents and pressure.

Equilibrium swelling time

Swelling time is time taken by the hydrogel to attain its equilibrium swelling point where swelling is stopped. Swelling is mostly measured gravimetrically and volumetrically, a texture analyzer is used to measure swelling time. Dried superporous hydrogel is allowed to hydrate in excess of swelling medium (25ml) at room temperature. At various time intervals, hydrogel is removed from solution and weighed after excess solution on the surface is blotted.

Equilibrium swelling ratio

Measured weight of dried superporous hydrogel and allowed to hydrate in distilled water at room temperature. At various time intervals measured weight. Equilibrium swelling ratio is calculated by using this formula;

$$Q_S = (W_S - W_d) / (W_d \times 100)$$

W_s is weight of welled hydrogel, W_d is weight of dried hydrogel and Q_s is equilibrium swelling ratio. Swelling/de-swelling behaviors of superporous hydrogels is examined

by repeating same experiments at two different pH, pH 7.0 and pH 1.2.[7,10,20]

Swelling reversibility

Pulsatile pH dependent swelling of superporous hydrogels is evaluated by alternation of swelling medium between the 0.1N HCl solution (pH 1.2) and phosuperporous hydrogelate buffered solution (pH 7.4). Hydrogels is first swollen in pH 1.2 HCl solutions for 30 min. and weighed at given time, then transferred to phosuperporous hydrogelate buffered solution. Same procedures are performed for swelling in phosuperporous hydrogelate buffered solution before transferring swollen hydrogels back to the HCl solution. Hydrogels is transferred to alternating solutions every 30 m.[7]

Stability studies

Sample are kept in airtight containers and stored in stability chamber at 40 °C / 75% RH for three months. In vitro dissolution study data obtained after three months will be compared with the data obtained at the time of preparation.[4,22]

Gelation Kinetics

As polymerization reaction proceeds, viscosity continuously increases until full network gel structure is formed. Gelation time is measured by simple tilting method after adjustment of pH to 5.0 with acetic acid. It is determined by the duration of time taken by reactant mixture to become viscous and henceforth viscous solution no longer falls down in tilted tube position.[7,10]

In-vitro drug release studies

Release rate of drug from Superporous hydrogels is carried out at 37± 0.5°C in 900ml stimulated gastric fluid SGF of 0.1N HCl using USP paddle type. Medium is stirred at 50rpm and 5ml aliquots are withdrawn at specified time intervals, maintain sink conditions, then assayed spectrophotometrically to get cumulative percentage of drug release.[5,7]

APPLICATIONS OF SUPERPOROUS HYDROGEL

Sustained Drug Delivery

Gastroretentive system is most beneficial for drugs that act locally in stomach (antacids, antibiotics). Controlled release is improving bioavailability of drugs with narrow absorption window (riboflavin, levodopa). These systems have a bulk density of less than one so they are floating on gastric contents or relatively large in size so that cannot pass through pyloric opening. As swelling properties of both superporous hydrogel and composite are ph-dependent, these can be used as pH-sensitive drug delivery systems.[17,24,26]

Site-Specific Drug Delivery

Riboflavin and furosemide are absorbed from stomach or proximal part of small intestine. A bilayer-floating capsule was developed for local delivery of misoprostol. By targeting slow delivery of misoprostol to stomach desired therapeutic levels could be achieved and drug waste could be reduced. HEMA based pH sensitive polymeric network has been reported as self regulated device for insulin delivery (Klumb and Horbett 1992).[10,27]

Gastroretentive Tablets

Superporous hydrogel particles of acrylic acid /sulfopropyl acrylate copolymers are mixed with gelatin and tannic acid then tableted by direct compression. Formation of hydrogen bond between gelatin and tannic acid, as well as carboxyl groups on polymeric carrier, produce an integrated matrix, which is stable after swelling. Gastroretentive tablet can swell up to 22 times its own volume within a 40 min.[28,29]

Peroral Peptide Delivery Systems

The feasibility of using Conventional Superporous hydrogels and Composites for peroral peptide delivery has been investigated. They are designed to swell in intestine with Superporous hydrogels physically adhering to gut wall and delivering incorporated peptide directly to the site.[30,31]

Fast-Dissolving Tablets

Methods used to prepare fast-melting tablets are freeze-drying, sublimation and direct compression. First two methods make tablets that dissolve within 5–15 seconds. Tablets prepared by direct compression using superporous hydrogel micro particles disintegrate less than 10 sec.[17,31]

Diet Aid

Superporous hydrogels can occupy significant portion of stomach space leaving less space for food, thereby suppressing appetite. This can help to lose weight in obese people. Maintaining integrity and volume of swollen superporous hydrogel is major challenge in use of weight loss aid.[19,31]

Chemoembolization

Chemoembolization is combined method of embolization and chemotherapy. Embolization is use in the treatment of cancer by restricting oxygen supply to growing tumours. A chemotherapeutic agent and anti-angiogenic agent can be loaded into Superporous hydrogels for chemoembolization therapy. The strong Superporous hydrogels are better candidates for this application.[10,17]

Occlusion Devices for Aneurysum

In the treatment of aneurysms Superporous hydrogels is used. Smaller size hydrogels devices prepare and placed at the aneurysm site, which quickly swells to occupy full space and form blood clot. Deposition of superporous hydrogels can result in up to 95% aneurysm occlusion without any evidence of parent artery compromise and inflammatory response. A new occlusion device prepared by combination of superporous hydrogel and platinum coils, called as Hydrocoil.[19,31]

Novel drug delivery

Here we found a platform scaffold technology that would be further examined for tissue engineering application. Superporous hydrogels composites based on aqueous Carbopol solution are good candidate for transmucosal drug delivery system. With superporous hydrogel self-nano emulsifying drug delivery system was formulate which contain containing carvedilol. Superporous hydrogels may be use as solid carrier in pharmaceutical field.[32-34]

Other Applications

Used of Superporous hydrogels other than pharmaceutical and biomedical are sanitary products, agriculture, bioseparation, enhanced oil recovery, hygiene, Diaper, horticulture, pet, colored Superporous hydrogels in decoration. Superporous hydrogels may be suitable substitute for silica gel. High swelling pressure of Superporous hydrogels can be used to trigger an alarm system upon penetration of water.[32,35]

Table 2: Applications of Superporous Hydrogels[19]

Application Types	Drug
Local drug delivery in stomach	Misoprostol
Oral drug delivery	Insulin
Peroral drug delivery	Buserelin, Octreotide, Insulin
Intestinal drug delivery	Desmopressin
Superdisintigrant	Ketoprofen fast disintegrating Tablets
Gastroretentive drug delivery system	Rosiglitazone

SUMMARY

Superporous hydrogel are a novel class of hydrogel. The unique characteristics of superporous hydrogels open a new field of application in controlled drug delivery. Modern Superporous hydrogels have high swelling and high mechanical strength making them suitable for many diverse pharmaceutical and biomedical applications. Different generations of Superporous hydrogels have been developed to accomplish the needs for certain applications. However, demonstrative preclinical animal studies still need to be confirmed in human trials, to further address safety issues and confirm therapeutic success when using Superporous hydrogels as platforms for drug delivery.

CONCLUSION

The focus of forthcoming applications of Superporous hydrogels is likely to be in the area solid and semi-solid dosage formulation in oral site-specific delivery and regenerative medicine. Researcher looks for usefulness of superporous hydrogel in various Pharmaceutical fields where fast swelling property is required. Superporous hydrogel can be use as a drug carrier in biomedical application.

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