REVIEW ARTICLE

Nanosponges: Revolutionizing Medical and Pharmaceutical Sciences

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ABSTRACT

Long-term efforts to develop a system which will not be hampered by the complex long process which is needed to create a good dose delivery system. It is due to mixture of both water loving and hating drug categories. A system consists of good nanotechnology to prepare sponges which will be of nanosized and will provide a good result and potency and to detect an activity causing toxicity, reducing rate of absorption and good release of active constituent. Due to reduction in size and having pores with good 3D structure. This properties will be effective in treating various symptoms or disease like cancer, disease related to autoimmune system. This data will help in providing basic information about good and bad effects with mode of methods to prepare and to characterize with maximum expansion in developing nanosponges.

Keywords Nanosponges, bioavailability, stability, theranostic, systems.

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INTRODUCTION

The small size less than that structure termed as nano in relation to sponges which resemble mesh, that have the ability to contain a wide range of materials, including drug molecules.[1,2] They have a spherical colloidal structure (**Figure1**) and improve the solubilization ability of both lipid- and water-soluble medicines.[3] They make medications with extended drug release more bioavailable.[4] Hydrophilic and hydrophobic medicinal compounds can be carried by nanosponges due to their amphiphilic nature, which is characterized by their outside hydrophilic branches and internal hydrophobic chambers.[5] With crosslinkers connecting various polymer segments and the solutions long-chain polyester backbone, they resemble a three-dimensional network.[6] It is seen that reaction of cyclodextrin with linking agents for crossing. It is a special type of nano form composed of excess -connected cyclodextrins can be created.[7] Nano form can be created by various materials with different nature like acidic or neutral, which swellbased on the crosslinker agent used.[8] As a result, voids and hollow spheres that can contain medication molecules are produced. This proportion can be maintained by maintaining good load of drug. The content of drug which will have same ability as nano sponge form and their involvement with non-involved interactions with each content. They have several advantages over other nanoparticles in that they may be readily replicated using a variety of processes, including mild heating, stripping with safe hot gases, washing with eco-friendly solvents, and adjusting solutions with their ions or molecule strength.[9] pharmacological component can circulate freely among the nanosponges because of several voids in their core architecture. Due to the contained moiety's freedom of movement within the vehicle, the drug concentration is lowered, disturbing the delicate balance and resulting in an unsaturated state. the linking agent allow the formulation to cling at active site with selectivity.[2] They are a feasible method of delivering medication because they have been demonstrated make a release from any problem.[9] Due to their tiny size, nanosponges can be injected into veins and lungs.[10] The prepared form can be spread in a sample of matrix consist of excipients to bind, dilute with some quality to maintain cake formation. The drug can be administered parenterally through preparing dilution in water free from impurity or other hydrophilic form.[11] The nanosponges can be formulated in different types as shown in Figure 2.

Benefits of Nanoparticles

Drug distribution to specific sites is achieved by nanosponges. Less detrimental side effects. Because the particles of the nanosponges dissolve in water, the hydrophobic medications can be enclosed in the nanosponges. Prevents giving the therapy in excess or insufficiently. More elegance, more stability, and more formulation freedom. Systems using nanosponges are non-toxic, non-mutagenic, non-irritating, and non-allergic.

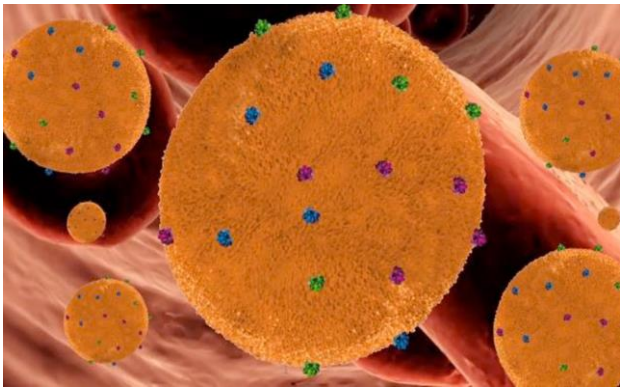

Figure 1: Nanosponges

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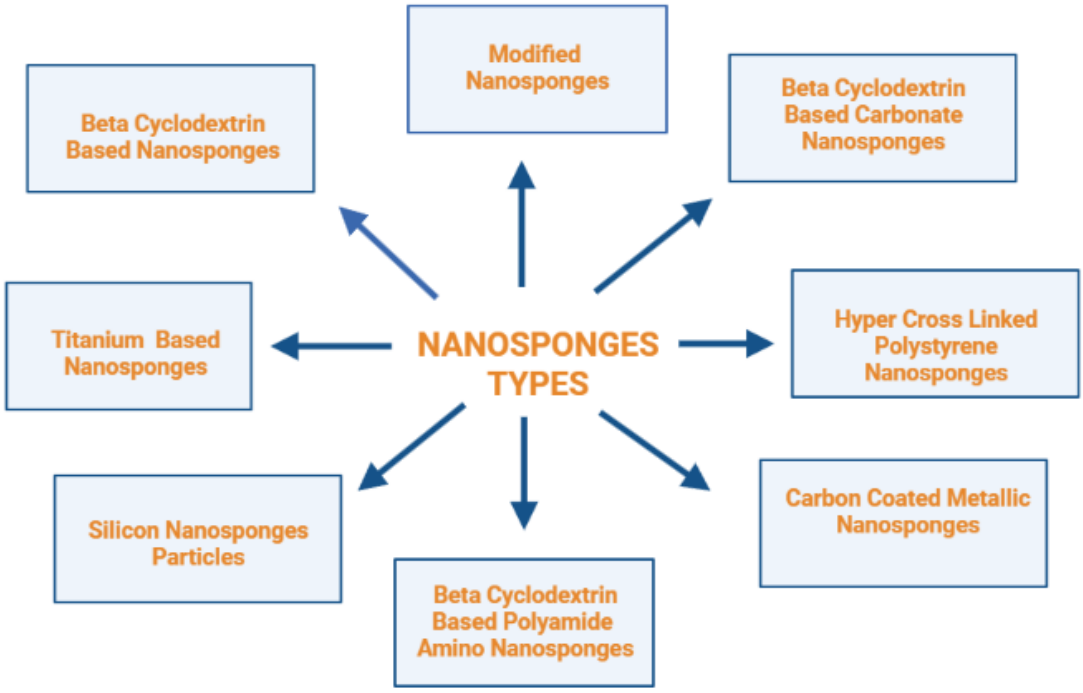

Figure 2: Types of Nanosponges

Because of their 0.25µm average pore size, which prevents germs from penetrating, they are self-sterilizing.[7]

Negative Aspects of Nanosponges

Their restriction to tiny molecules. Rely solely on the medication molecules' loading capabilities. The Level of crystal formation decide capacity of sponges in nano form. The API entrapment efficiency is low, larger sizes result in increased pore width and a higher rate of dissolving, which affects the formulation's control release. When exposed to water, nanosponges swell, modifying both their release rate and nanosize.[4,7]

How Drugs are Released from Formulation

The drug molecule can freely flow through the numerous holes in the nanosponges structures that are present in their core once the liquid reaches the drug molecule's saturation point. The final product is then applied topically or ingested; the moiety enclosed is free to move within the vehicle and is subsequently absorbed through the skin.[12,13] The process of releasing API from nanosponges typically involves several factors, including the properties of the nanosponges material, the encapsulated drug, and the environmental conditions. A general overview of the mechanisms involved is presented in Figure 3.

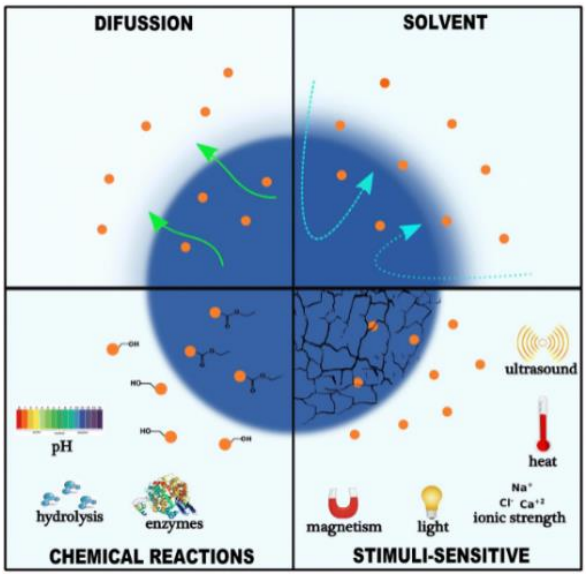

Figure 3: Drug Providing Effect from Formulation

Diffusion

One common PROCESS is diffusion. In this process, the drug molecules move from areas of high concentration within the nanosponge to areas of lower concentration in the surrounding medium. This can occur through the pores or channels within the nanosponge material.

Swelling and Erosion

Some nanosponge formulations are designed to swell or undergo erosion in process to environmental factors like changes in Physical and chemical conditions, or solvent composition. As the nanosponge swells or erodes, it releases the encapsulated drug molecules into the surrounding medium.

Desorption

Drug molecules may be adsorbed or bound to the layer of the nanosponge form with less bond like hydrogen bonding. Release can occur through desorption, where the drug molecules detach from the nanosponge surface and diffuse into the surrounding medium.

Chemical Degradation

In certain cases, the nanosponge material may undergo chemical degradation or cleavage in response to specific environmental conditions. This degradation can lead to the release of encapsulated drug molecules that were

chemically bound or conjugated to the nanosponge material.

External Stimuli

Some nanosponge formulations are engineered to respond external stimuli such as light, magnetic fields, or ultrasound. These stimuli can trigger changes formulation or properties, giving efficient factor for liberating of encapsulated drug molecules.

Controlled Release Strategies

Various controlled release strategies are used to modify or to increase rate and extent of active constituent release from formulation. These strategies include the use of stimuli-responsive materials, surface modifications, and the incorporation of additional excipients or polymers to tailor the release kinetics according to specific therapeutic needs. Overall, liberation of API within nanosponges can vary depending on formulation design, the properties of the encapsulated drug, and the desired release profile.[13]

Key Characteristics

Nanosponges consist of a particular size of particle and can be made polar or non-polar by adjusting the proportions of polymers to crosslinking agents. Nanosponges have sizes of less than 1 μm and vary in void polarity.[14]It is discovered that they remain stable at high temperatures 140° c and potential of hydrogen of 2–12. it is discovered that they are non-toxic, biodegradable, and porous in nature.[15]Crystalline or para-crystalline forms are possible. since productivity of stacking nanosponges is significantly influenced by the degree of crystallization, crystal from sponges as crucial for networking of active constituent in paracrystalline, reports that a variety of drug-loading capabilities of nanosponges have been demonstrated.[3] The capacity to meet several structures, they exhibit targeted release of different molecules. this can be enhanced by employing chemical interaction that specifically act on particular site.[2] The preferred material is nanosponges because they can encapsulate immiscible liquids and offer prolonged medication release for up to 24 hours while also causing less discomfort and increasing flexibility and stability.[2] It regulates the maximum free part in sponges of nano form for filling, the degree with crosslinking affects capacity to load medicines.[16]

Materials Utilized to Prepare Nanosponges

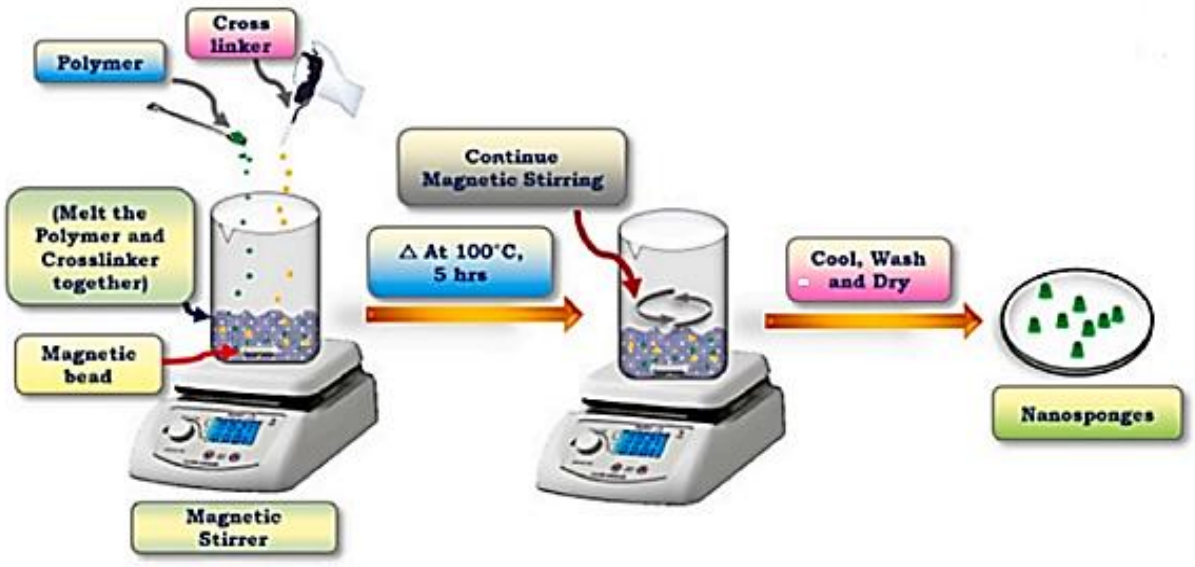

Figure 4: Formulation methods of Nanosponges by Hyper crosslinked method

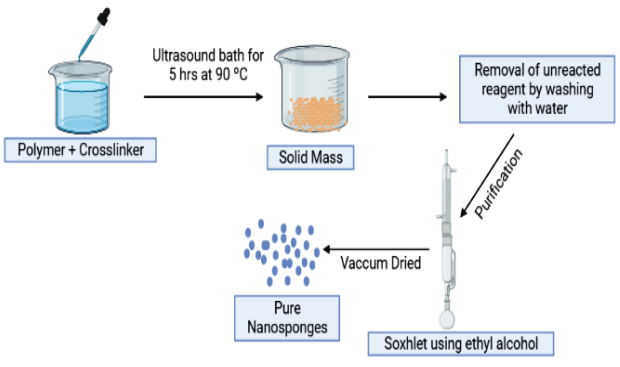

Figure 5: Formulation methods of Nanosponges byUltrasound-assisted synthesis

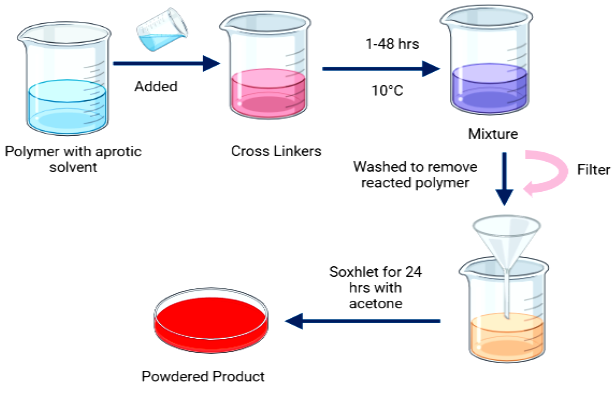

Figure 6: Process of Preparation by Dissolvent method

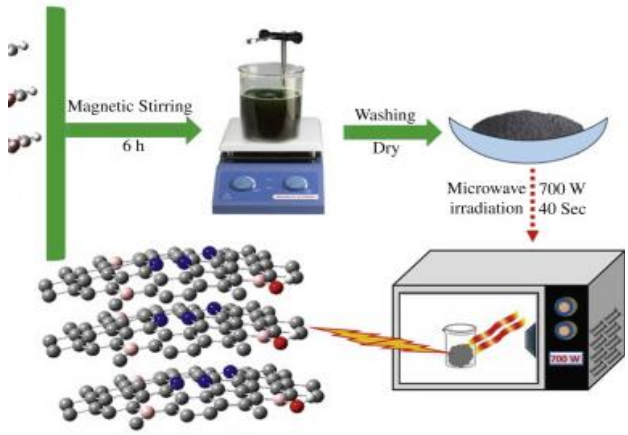

Figure. 8: Formulation Method of Nanosponges byMicrowave Irradiation Method

Table 1: Applications of Nanosponges

Drug	Carrier	Inference	Ref.
Niacinamide	Caraway formulation	Increase anti-microbial activity	17
Paclitaxel	Use of solvent in ethylcelullose	Mantained sustained release	19
Epirubicin	Hydrazine with dots.	Provided therapeutic and diagnostic effect	45
Cisplatin	High cross linker cyclodextrin form	Increase permeation in different spheroids	18

Various chemicals have demonstrated encouraging outcomes and can be employed in the production of nanosponges, contingent upon the intended nanosponge type and the essential level of crosslinking. the next section discusses various ingredients utilized in the creation of nano form.[16]

Polymers and copolymers

Variety of resin form used in formulation of nanosponges has an impact on their development and functionality. the kind of medication to be encapsulated and the intended release profile also influence the polymer choice. Among the polymers that are employed include acrylic polymers, eudragit rs100, hypercrosslinked polystyrenes, and cyclodextrin and its derivatives.[17,18] Hafiz et al. used nanosponges as a carrier to create a carboplatin hydrogel. Using a double emulsion solvent evaporation process, ethyl cellulose was used to produce the nanosponges. Improved medication providing effect at given site for sustained release and adherence was demonstrated by the hydrogels containing nanosponges that were synthesized.[19, 20]

The proportion of polymer employed as copolymers increased the drug's inclusion as demonstrated by abelaciclovir-containing nano form made, the findings showed that good encapsulation efficiency and the prevention of drug leakage from nanosponges are achieved when there is a higher concentration polymer and a lower concentration of Pluronic F-68.[21]

Crosslinking agent

The drug whose nanosponges are to be prepared and the polymer's structure determine the kind of crosslinker to be used.[17] among the crosslinking agents utilized are Cdm, COOH, types of imidazol.[18] Crosslinking quantity, which depends on crosslinker concentration, is an essential part of nanosponges because it affects liberation of drug format.

By varying the crosslinker concentration, it is possible to produce hydrophilic or hydrophobic nanosponges to relaese active content. Moreover, distinct crosslinking agents have the ability to dramatically change critical properties such as the polymer's swelling capacity and hydrophilicity or hydrophobicity.[22] Using triazole as a linker, Massaro et al. suggested creating cyclodextrin-calixarene copolymers to improve the binding qualities of standard cyclodextrin nanosponges. employing this combination of cyclodextrin-calixarene Nanosponge materials, composites were produced employing two polyphenolic bioactive compounds, quercetin and silibinin.[23,24]

Drug Substances

To be formed as nanosponges, the drugs molecular weight should be between 200 and 300 Dalton. Around less 10 mg/ml substance should be diluted in water with providing fusion process around 240 °C. Drug compounds should also have fewer than five condensed rings.[25-29]

Strategies for Creating Nanosponges

Hyper cross-linked method (Melting method)

Around 16.43 g of caraway and around 90-100 ml of DMF were added to RBF, dilution is prepared and mixed hard till it gets completely break down. this mixture was treated to 9.86 g of cdi, and the reaction was run for 4 hours at 100 ◦C. To remove any surplus Dimethyl Formamide from the combination above, a large amount of deionized water should be added. Lastly, unreacted compounds are removed using ethanol-based Soxhlet extraction, as seen in **Figure 4.**[30,31]

Ultrasound-assisted Synthesis

With this technique, polymers and crosslinkers react under sonication to create nanosponges without the need for a solvent. with this technique, spherical, uniformly sized nanosponges are obtained. in this process, crosslinkers like pyromellic anhydride or phenyl carbonate are agitated in apparatus with good ratio.the mixture in the flask w kept ultrasonic apparatus with h20 and was heated around 100^0 c when it had cooled. to remove any remaining nonreacted polymer, the mixture is washed with water [**Figure 5**]. The combination is refined using an extended soxhlet extraction procedure with ethanol.[30,32]

Solvent Method

Using this procedure, a polymer solution is added in excess to the crosslinker, and the temperature is kept at 10-15^0C for 2 days. Sample was letter chilled and given a good ration of solvent which causes nanosponges to develop. Following preparation, the nanosponges were collected and vacuum-filtered [**Figure 6**]. The combination is refined using an extended Soxhlet extraction procedure with ethanol.[30,33]

Polymerization

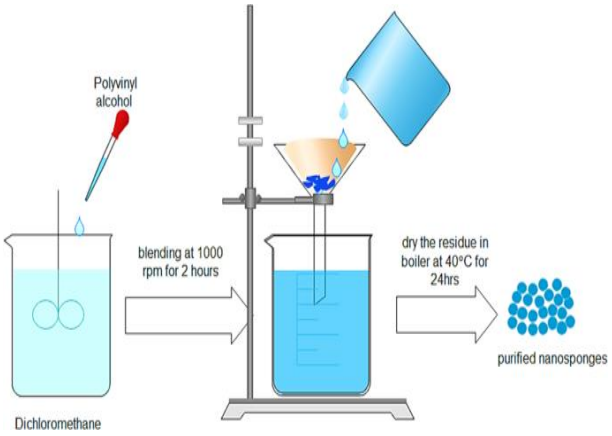

Figure 7: Formulation methods of Nanosponges by QESD-CC

After dissolving a non-polar drug of single molecule in water phase, water part consisting of surfactants and dispersants to facilitate suspensions are mixed. Breaking the monomers increase in physical conditions is how polymerization is done containing the separate drops of essential dimension required size is produced. The Chemical process produces a system that resembles a reservoir and providing opening through orifice present.[17]

Quasi-Emulsion Solvent Diffusion

This technique prepares nanosponges by using aqueous and organic phases in varying ratios. Polyvinyl alcohol is employed in the aqueous phase, whereas a medication and polymer solution are used in the organic phase. After choosing the polymer and dissolving the medication in an appropriate organic solvent, the mixture is gradually introduced to the aqueous phase. The final mixture is agitated at 1000 rpm for over two hours [**Figure 7**]. Filtration, washing, and drying are done on the prepared nanosponges.[30,34]

Microwave Irradiation Method

The temperature of the reaction mixture was measured by inserting a structureed cloth inquest in container. carbonate of diphenyl was employed as a linking agent for crossing and DFM as a solvent to produce cyclodextrin-based nanosponges. In short, a 250 ml flask was filled with a solution of cyclodextrin and diphenyl carbonate in dimethylformamide, and microwaved for a predetermined amount of time under particular conditions. The solvent was totally eliminated after some time. After that, the final product was extensively cleaned using ethanol and Soxhlet extraction **[Figure. 8].** After that, a white powder was created, which was subsequently dried at 60 °C in an oven to make it usable.[2,26]

Elements that Influence the Development of Nanosponges

Variety of multiple monomers & Cross linkers

The type of multiple monomers employed for preparation of nanosponges has an impact on their performance. crosslinkers that work effectively can create three-dimensional structures from nanoporous molecules. by adjusting the degree of crosslinking, hydrophilic or hydrophobic portions can be created that entangle target molecules. water soluble or insoluble nanosponges are created based on the crosslinkers' properties.[35] water loving form can be created by using epichlorohydrin as a agent for crossing. these can be used as efficient drug carriers and improve medication absorption across biological membranes.[36] hydrophobic nanosponges that can be used to distribute hydrophilic medicines, including proteins and peptides, for a longer duration can be created by employing crosslinkers like diphenylcarbonate,[37] pyromellitic anhydride and diisocyanates.[38]

Kind of medication and interaction medium

The kind and nature of the crosslinker and polymer utilized, along with the kind of medication that must be loaded,

Table 2: Patents of Nanosponges

No.	Patent title	Patent number	Inventor	Year	Country
1	Electrostatic precipitator assembly and electrostatic air cleaner with conducting synthetic polymer plates	US-20240017272-A1	Krichtafovitch; Igor	2024	USA
2	Minoxidil adjuvant therapies	US-20240009101-A1	Goren; Ofer	2024	USA
3	Antiviral therapy with imiquimod and cocrystals thereof	US-20230226028-A1	DANDIKER	2023	USA
4	Topical Aerosol Foams	US-20230190651-A1	OSBORNE	2023	USA
5	Anti-fungal preparation with curcumin and luliconazole nanosponges	202121024881	Jayadeep R. Yadav	2021	India
6.	A method for producing stable lithium silicate nanosponges for capturing CO2	202021008717	Vivek Polshettiwar Rajesh Belgamwar	2020	India
7	Reconstituable hydrogel powder of dapsonenanosponges useful in the treatment of acne	201821029366	Dhamane suchita prabhakar Sonar Sagar Suresh	2018	India
8	Synthesis of Nanoparticles and nanosponges	US09574136 B2	Kun Lian	2017	USA
9	Polycarbonate-containing compounds and methods	US 09580548B2	Eva M. Harth David M. Stevens	2017	USA
10	Starch nanosponges	2071/MUM/2014	Vavia Pradeep Ratila Jadhav Nitin Vitthalrao	2016	India

might all affect the formation of nanosponges. it is possible to efficiently capture drug molecules inside a nano structure if they are having molecular weight between 200 and 500 da, a m.p below 240 ◦c, reduce fused ring in number of five, and dissolving form below 15 mg/l in aqueous form.[39]

The condition for marinating firmness constants decreases with increasing temperature due to the weakening of drug or nanosponge contact forces. Consequently, careful temperature control should be maintained when creating nanosponges.[31]

Furthermore, melting compounds at higher temperatures leads to less drug loading because of the structural rigidity of the compounds. While organic solvents tend to liberate trapped organic molecules in Nanosponges, hydrophilic media will force organic guest molecules to enter hydrophobic cavities.[2]

Level of Replacement

The type of sub part, No., and site of molecule consisting multiple monomers all influence balance of nanosponges to complex.[40] The kind of replacement is required as surface chemical from of cyclodextrin derivatives provide wide accessibility to the derivatives in different forms, when distinct functional groups are complexed together by a crosslinker, several types of mixed material, such as mixed starch form can be generated. This implies that increasing the number of substituents may raise the possibility of higher crosslinking levels, which may result in very porous nanosponges because of the creation of a mesh-like network and enhanced links between polymers.[2]

Temperature

Temperature changes have an impact on how well nanosponges complexify. Usually, when temperature rises, firmness of active constituent falls. This could be because of decreased hydrophobic condition and less bond interaction like hydrogen bond forces.[31,40]

Properties of Nano form in sponges

The potency, degree of crosslinking, and speed of medication distribution of the Nanosponges are evaluated using a battery of tests, all of which contribute to the determination of whether the formulation possesses the necessary properties.[10]

Microscopic Analysis

Both scanning and transmission Electron microscopes allow for the microscopical study of drugs and nanosponges.[5] The electron microscope image demonstrates obtaining mixed form by comparing final product's rate of crystallization formation to that of initial materials.[40,41]

Solubility Analysis

The inclusion complexation process is studied using the phase solubility approach. The medication was added to each flask that held an aqueous solution of different percentages of nanosponges in this technique. A mechanical shaker was used to shake the flask while it was at room temperature. Following centrifugation, the coarse dispersion was filtered through a 2500 Dalton molecule filtration once it had stabilized. HPLC was used to examine the resulting solution and determine the drug content. The pH of the medicine, the solubilization process, and the factors influencing drug solubility are all studied in relation to medication solubility.[41]

Thermodynamic Analysis

Any changes that medication particles or molecules undergo prior to the heat-induced loss of sponges can be found using the thermo-chemical method. Medication particles may change due to a variety of processes, including melting, oxidation, and polymeric changes.[31] Analysis of broadening, transferring, to introduce new range and to remove old range the introduction of new peaks, and the removal of specific peaks can be done using the thermogram produced by DTA and DSC.[41,42]

Thin Layer Chromatography (TLC)

The evaluation of a drug molecules Rf values in TLC facilitates the identification of the drugs complex creation with nanosponges.[41,42]

Drug Loading Efficiency

The drug injected in the nanosponges was quantitatively estimated using a UV spectrophotometer.[32] You can use the following formula to ascertain how much medication is added to nanosponges.[4,41]

% **Loading capacity** = (Drug in nano sponge / Total amount of drug and polymer added) × 100

Vibrational spectroscopy

Infrared spectroscopy is utilized to ascertain how pharmacological molecules interact with nanosponges in the solid state. bands on nanosponges width somewhat when a compound forms. the bands of the nanosponges spectrum easily mask form to be attributed to the extra molecules below 22-25% are included in complex.[43] Use of IR is limited to drugs that have identifiable width, like sulfonyl or carbonyl groups.[41]

Micromeritics

A big size of particle more the 100 sensorn are applied for measurement via dynamic light scattering. This makes it possible to estimate the mean diameter and polydispersity index.[5] It was measured at certain angle around 90 for every sample. The product was suitably mixed with water in milli q every assessment.[1,41]

Zeta potential

Used to assess surface charge.[5] To find the zeta potential of sponges in nano form, samples mixed with 0.01 mol/l KCL.

X-ray Diffractometry

To measure complex form of solid state. Diffraction peaks can be used to determine the intricate growth and chemical breakdown of a mixture of substances. The drug's crystalline structure and diffraction patterns are altered during the formation of the drug-nanosponge combination.[41,45]

Applications

Biocompatibility and adaptability make Nanosponges a versatile tool with a multitude of possible applications in the field of nanotechnology. Nanosponges have several uses, some of which are covered in this article.[46-48] **Table 1** lists a number of more recent uses for Nanosponges along with an indication of their relative significance.

Cancer

Hyper-cross-linked polymers that create nanoporous systems are the building blocks of new drug delivery methods, and cyclodextrin-based nanosponges are among

them.[1,10] One of the main disadvantages of many anticancer drugs is their extremely low water solubility. Nanosponges can enhance the solubility and wetting of molecules with very low water solubility.[49-52]

Utilizing cyclodextrin nanosponges acting as soluble form a, Studies on short-term stability have shown that drug loaded formulation stored in a given solution provide stability for long term studies.[53] The drug loaded sponges kept at 3-4°C as a water form produced a good without forming paclitaxel crystals.[52]

Use of nano sponges to administer paclitaxel, it is easy to eliminate the toxic ingredient Chremophor EL formulation, increase the amount of drug given penetrates cells causing cancer, and lower drugs 50% concentration inhibition improve the drug's pharmacological action.[52,54]

The findings of 2 cancer causing form looked at less growth of cancerous cells in relation to breast in animals and speedy mouse gliomas. In both the condition the use of nano form for medication delivery increased cancer cell death and suppressed tumor development.[30]

Asakiya *et al.,* created a potential of gradient nanoform for the active site. capsaicin and doxorubicin to tumour of colon and rectal form. together, the two medication combinations filled into sponges of DNA decreased the potential of the mitochondrial membrane, produced cellular species containing o2, and inhibited the growth of sw480 cells.[55]

Fungal Infections

To improve the solubility, stability, and controlled release of clobetasol propionate β-cyclodextrin and diphenyl carbonate hydrogel. the thp1 cell line was used for the in-movement test. The outcomes demonstrated the superior payload and controlled-release capabilities of clobetasol propionate nanosponges. furthermore, in vitro experiments showed that it was efficient against thp1 cells, exhibiting immune-modulatory and anti-inflammatory properties.

A butenafine gel based on nanosponge was developed by ahmed et al. to treat fungal infections. through deeper delivery of medications to active site into outer layer of skin., nanocarriers improve the efficacy of treatment and eradicate fungal infections entirely. by extending the duration of the drug release, the recently developed carbopol polymeric gel impregnated with butenafine loaded nanosponge may prove to be a successful drug delivery method for the treatment of fungal diseases.[56]

Covid

sponges in nano form consisting of cyclo having starch paste, which have cooh groups in their s composition, have been used to transport acyclovir. these nanosponges work well for sustained release and have higher capacity for opposing viral drug; nevertheless, more in vivo testing is required to properly assess the effectiveness and spreading of these sponges.[57]

In Drug Delivery

Good dosage form can be obtained, such as topical, parenteral, aerosol, tablet, and capsule, due to their circular shape andnano size.[58] Econazole nitrate is an antifungal drug that can be used topically to the skin in the form of cream, lotion, ointment, or solution to relieve the symptoms of skin infections, dermatophytosis, and superficial candidiasis. The restricted absorption of econazole nitrate upon topical application restricts the medication's ability to treat certain conditions.[59-60]

It is feasible to effectively deliver medicine whose dissolving property is crucial for preparation by loading drugs into the nanosponges. Nanosponges can be used to disguise bad tastes and solidify liquids, as well as enhance dissolving property stability and dissolution rate, stability, and dissolution rate.[61]

Telmisartan, a drug of second class of BCS, has a bioavailability that is stopped by its rate of dissolution. Nano form of sponges using crosslinkers such as cyclodextrin having different bonds.tel was present in the sponges in nanoform it's in vitro dissolution solubility at which it stops getting dissolved was compared. the solubility of Telmisartan was found to be increased 9.53-fold in distilled water, in various proportion in HCl and sodium bicarbonate.

Transport of Peptides and Proteins

The medications were not properly absorbed and were not able to cross the membrane because their size was big and other factors line ionization with less permeable across membrane of mucus. After IV the molecules of protein get extracted very fast from the blood the attached to plasma proteins and enhance the reaction. Bioavailability is the problem with oral delivery. Protein development depends critically on their long-term stability.[62]

In addition to enhancing protein stability, nanosponges can control movement, stability and covering of proteins.[30,32] It has been found that highly efficient carriers for protein adsorption are nanosponges based on cyclodextrin.[32]

Autoimmune Diseases

When an autoimmune disease occurs, the body's defensive mechanism overreacts, attacking itself. the development of biomimetic nanoparticles, which take their cues came from environment increased the connection between chemical form of material and living form, has attracted more form recently in the field of nanomedicine.[63-66] Toxic chemicals are bound by nanosponges and neutralized, preventing harm to healthy cells. the nanosponge provided a position strategy to provide extended form to maintain balance, which distinguishes it from regular nano form process works with parallel structure.[67] Numerous orifices forming material came from venom or different type of streptococcus form have been provided by this theory,[67-69] all the toxins are incubated with RBC covered with nano sponges and due to that it reduced cell membrane or layer of sponges.[70]

A red blood cell-based nanosponge formulation was developed to treat autoimmune hemolytic anemia. the RBC layer was covered with core of polymer to form an RBC containing antibody nano form which will maintain affinity as residing form of RBC group. this formulation show efficacy in stopping the opposed form of RBC from joining to good and healthy RBC in both conditions.[71]

Blood Poison

Nanosponges provide a novel approach to blood detoxification. By infusing the toxins into their bloodstream, nanosponges can absorb the toxins in place of an antidote. By mimicking red blood cells, these nanosponges mislead the toxic form from attacking them

and provide extent of absorption, absorb them, and reroute their course away from the intended target cell.[72]

Photo thermal Therapy

it was discovered that conventional phototherapy was useless since it was damaging not just cancer cells but also healthy cells. photothermal therapy based on nanocarriers appears promise since the carrier of nano form with less activation or heated form can be targeted to the tumor site. by restricting the heat ablation to the tumor location, this lessens the death of normal, healthy tissues or cells.[73]

Jin et al. created deoxy ribozyme nanosponges using the approved dye indocyamine for photothermal therapy. compared to the indocyanine green group, the temperature rose significantly greater in nanosponges. this technique is providing for mainating gene therapy because anti-cancer studies may get affected by photo having heat without any harmful effects.[74, 75]

Additional Uses

Using an amino acid and a solvent, Huang *et al*. created silver (Ag) nanosponges which is used as Raman effect substrates to find minuscule concentrations of dangerous antibiotics and chemical dyes. Using (R6G) as a form, the effectiveness of surface increased Raman scattering was investigated. The results showed that a particular silver nano form showing good Raman effect. The detection of pazufloxacin mesylate (PM) was facilitated by these uniform nanosponges, which acted as Raman effect showing adsorption form.

A gel based on hesperetin nanosponges was developed, improved, and assessed by Rodrigues et al. extending agents against swelling. When compared to pure drug and physical combination, minute, orifice, circular dramatically slowed down the liberation of Active constituent. There was no sign of skin inflammation. Furthermore, rats treated with hesperetin showed 33.16% less suppression of inflammation than the control group. Hesperetin bioavailability issues were potentially resolved by using nanosponges, which also reduced topical dissemination.[27]

Utzeri et al. created their cyclodextrin-based nanosponges to study the sequestrating action of imidacloprid. For the preparation of nanosponges, two distinct linkers were utilized: dodecane-1,12-diamine (am12) and (am6). A Nanosponge containing Hexane-1,6-diamine (am6) offered a better sorbent activity for imidacloprid.[76]

for the fluorescence detection of diclofenac, it is producing cyclodextrin form of spongesacting as linker for crossing. pyromellitic anhydride as a crosslinker. fluorescence tests indicate that at an emission wavelength of about 423 nm, it exhibits a sparking attraction for NSAID like acelofenac different from codeine and other.[77]

The broad-spectrum mitigation capability of biologial layer of cell covbered with nanoform, often referred to cell form of nanosponges, is being utilized because it is challenging to achieve with traditional countermeasure technology. natural cell membranes are applied to the cores of synthetic nanoparticles to form these biological nanosponges. cellular nanosponges mimic the functions of real cells thanks to surface receptors inherited from donor cells. the researchers have used for biological neutralization. this idea states that all poisons, regardless of their structural form or required to interact with cells to be referred as bio active.[78]

FUTURE PERSPECTIVES

Pharmaceutical science has determined that the most popular drug delivery method is nanosponges. The efficient functionalization of nanosponges to lower toxicity, improve selectivity, and enhance biosafety should be the main emphasis of future study. It is possible to create new nanosponges with a range of properties and multifunctionality. More study is needed to focus towards precise function of nanosponges using various constituents like compounds exhibiting some fluorescence or particles with nano size having good quality. To produce a system providing good therapeutic conditions in terms of tumour and their treatment. Further process is required to prove the efficacy of sponges in nano form for proteins and peptides for oral condition. In future tis nanotechnology technique will be very effective for formation of nanosponges and to prove their potential.[79] In **Table 2**, some patents related with nanosponges formulation are showed.

CONCLUSION

Research has shown that nanosponge-based systemswhich have been found to have exceptional porosity, simple functionalization processes, unique topologies, affordability, and environmental friendliness make appealing replacements for targeted drug delivery. The most frequently examined nanosponges in nanomedicine are cyclodextrin ones because of their unique properties, outstanding biocompatibility, minimal harm, and ease of layer modification. By varying the concentration of material with monomer units and the ratio of cross linking, the right size can be achieved. Additionally, it protects them from degradation and helps make a variety of poorly soluble medications more soluble. Unlike other nanocarriers, the nanosponges can be used for a wide range of purposes, such as blood purification, targeting, enhancing dissolution rate with physical and chemical stable form, reducing degradation of active constituent, and boosting flexibility. It is worthy that whereas nanosponges exhibit encouraging outcomes in diverse domains such as system for delivering, tumour with more investigation with advancement are imperative for delineating characteristics, enhancing efficacy with proper and safe applications.

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