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Review Article

Exploring Microsponge Technology: Applications Beyond Topical Drug Delivery

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ABSTRACT

An ultra-innovative drug delivery method called Microsponge has been developed for oral or topical use. Entrapped medicinal compounds are shielded from physical and environmental deterioration by microsponges, which are porous microspheres composed of polymer and biologically inert. Microsponge sizes range from 5 to 300 µm in diameter. Microsponge delivery systems (MDS) have been the subject of several recent developments for the controlled release of medications onto the epidermis with the guarantee that the drug stays mostly localized and does not significantly enter the systemic circulation. MDS is a unique technology for the controlled release of topical medications. It is also utilized for the administration of oral medications and biopharmaceuticals, which include peptides, proteins, and DNA-based therapies. It is made up of microporous beads with diameters ranging from 10 to 25 microns, which are versatile enough to ensnaffle a variety of active substances. This review article includes information on patents and commercially available formulations along with techniques of preparation, release mechanism, characterisation, and uses of microsponge delivery systems.

INTRODUCTION

Drug Delivery systems (DDS), which regulate medication release or direct drug delivery to particular bodily locations, have a significant influence on the healthcare system. By combining the medication with different carriers, such as liposomes, neosomes, nanoparticles, microspheres, and so on, carrier technology offers an intelligent way to provide the medication and controls its release and absorption. These days, controlling the pace at which actives are delivered to the designated spot in the human body is one of the largest problems facing the pharmaceutical industry. Transdermal drug delivery systems (TDDS) are a group of dependable and consistent methods that were created for systemic

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medications by utilizing the skin as a portal of entry. It has enhanced the safety and effectiveness of numerous medications that might be better absorbed through the skin. Only recently has research successfully tackled the controlled release of pharmaceuticals onto the epidermis with the guarantee that the medication stays predominantly localized and does not reach the systemic circulation in substantial proportions. The main disadvantage of TDDS is that most medications have poor water solubility, which creates a number of problems when preparing them in traditional dosage forms. The inconsistent absorption and reduced bioavailability of poorly water-soluble medicines are two major problems. Due to their limited water solubility in both aqueous and organic mediums, BCS (Biopharmaceutical Classification System) class II medications face an even more challenging situation. Low solubility and irregular absorption can be addressed by a number of formulation strategies. These methods consist of Microionization, the use of co-solvents for solubilization, the use of permeation enhancers, surfactant dispersions, techniques for salt production and precipitation, etc. are some of these methods. While they demonstrate some effectiveness, other carrier strategies such as liposomes, neosomes, emulsions, microemulsions, solid-dispersions, and inclusion complexes utilizing cyclodextrin are not universally applicable to all medications. Therefore, a novel and uncomplicated method is required to address these issues[1].Additionally, there are numerous issues with topical medication application, such as greasiness, stickiness with ointments, and unappealingness, which ultimately results in low patient compliance[2]. These vehicles' ineffective delivery systems induce user irritation and allergic reactions, therefore substantial doses of API (Active Pharmaceutical Ingredients) are required for successful therapy.

All of these conditions are met by the microsponges delivery system (MDS), which also regulates the release of medications onto the skin's surface while ensuring that the drug stays localized on the skin's surface or inside the epidermis and does not significantly enter the bloodstream. They also have the benefit of programmable release and trapping of active medicinal components, which lessens adverse effects and improves formulation flexibility, stability, and elegance[1].

MICROSPONGE DRUG DELIVERY SYSTEM (MDDS)

Porous microspheres make up the patented Microsponges Drug Delivery System (MDDS), a polymeric technology[3].These microspheres are small, spherical particles that resemble sponges, and they have many interconnected vacuums in a non-collapsible structure. Their vast porous surface allows the active pharmacological components to be released gradually. Highly porous and cross-linked, microsponges are able to hold onto active substances such emollients, perfumes, sunscreen, essential oils, and antifungal, antibacterial, and anti-inflammatory agents[4].Porosity ranges from 5 to 300 μm, with a typical 25 μm sphere containing up to 2,50,000 pores. The interior pore structure has a pore volume of 1 ml/g5 and a maximum length of 10 feet. As a result, there is a lot of storage created. The pore volume in grams is between 0.1 and 0.3 cm^2/g.They are designed to distribute a pharmaceutically active ingredient efficiently at minimum dose and also offers better stability, with reduced side effects and modify drug release profiles. They can be included into conventional dosage forms such as Creams, Lotions, Gels, Ointments, Tablets and Powders, a broad package of benefits and thus produce formulation flexibility[7].

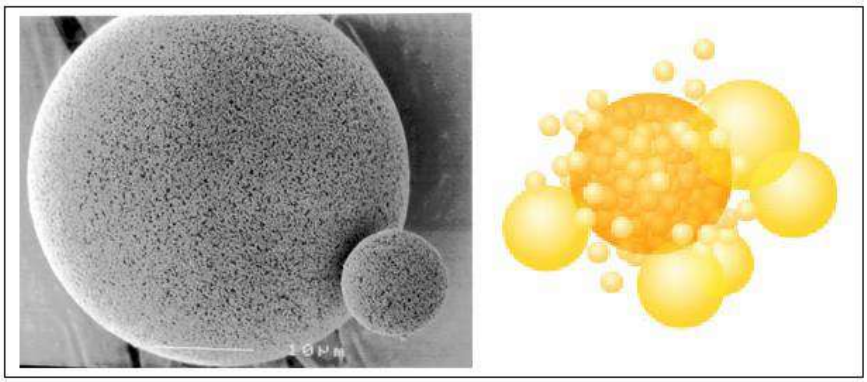

Fig.1 Morphology of Microsponges

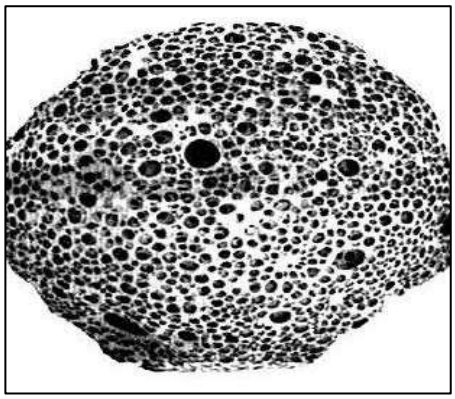

Fig.2 Highly porous nature of Microsponges

History of microsponges

Won created the microsponges technique in 1987, and Advanced Polymer Systems, Inc. (Redwood City, California, US) was given the original patents. This company created numerous variations of the techniques, which are used for both prescription and over-the-counter (OTC) pharmaceutical items in addition to cosmetics. Currently, Cardinal Health, Inc. has a license to employ this intriguing technology in topical medicines to enable controlled release of the active ingredient into the skin, thereby minimizing local cutaneous reactions to active pharmaceuticals and reducing systemic exposure.

2.2. Ideal properties of microsponges

1. Microsponges show acceptable stability over a wide range of pH (1 to 11)[5] .
2. Microsponges are stable at high temperatures up to 130 °C[5] .
3. Microsponges show good compatibility with various vehicles, excipients and active pharmaceutical ingredients.
4. Microsponges possess high entrapment efficiency or payload up to 50 to 60 % [9] .
5. Microsponges are featured by free-flowing properties and cost effective.
6. An average pore size of microsponges is 0.25 µm which is very less than average size of several micro-organisms, as a result prevention of their penetration. Hence, microsponges are called as self-sterilizing, no need of any kind of excipients (preservatives) and sterilization for stability purpose[5].
7. Microsponges are non-allergenic, non-irritating, non-mutagenic and non-toxic, non greasy.
8. Microsponges have entrapment capacity of API is up to 3 times of its weight.
9. Microsponges can absorbed oil up to 6 times of its weight without drying[5]
10. It provides continuous action up to 12 hrs i.e., extended release[10].

2.3. Advantages of microsponges

2.3.1.Advantages Over Conventional Formulations

Topical medication formulations that follow conventional methods are designed to target the skin's outer layers. When these products are applied, their active ingredients come out and form a highly concentrated layer that is quickly absorbed. Compared to the Microsponges system, it is able to stop an excessive build-up of components in the dermis and epidermis. It is possible that the Microsponges system will considerably lessen the irritation caused by

medications that work well without compromising their effectiveness. For instance, benzoyl peroxide formulations offer good efficiency with little irritation compared to MDS formulations because they distribute the active component to the skin gradually. Traditional topical preparations are solely meant to address localized issues like cuts, wounds, skin-surface bleeding, etc. Because these products absorb quickly into the skin and have less noticeable results, they have a high concentration of API.Because microsponges avoid excessive component buildup in the dermis and epidermis, they require a significantly smaller amount of API to demonstrate the necessary therapeutic activity than conventional formulations. Furthermore, Microsponges increase patient compliance and provide safety by reducing negative effects caused by API buildup on the skin's surface. Many topical formulations have uncontrolled evaporation of the active ingredient (API), which can lead to incompatibility. To address this issue, the formulation needs to contain a higher proportion of vehicle.

2.3.2. Advantages over Micro and Nano formulations

These days, the pharmaceutical industry is showing interest in microsponges, particularly in those that manufacture controlled release topical dosage forms. Because of their high drug loading capacity, simple formulation method, controlled release, physical, chemical, and microbial stability, and compatibility with a wide range of medications (including ketoprofen, benzyl peroxide, retinol, fluconazole, ibuprofen, tretinoin, trolamine, prednisolone, acyclovir sodium, and tioconazole), microsponges are superior to microspheres, microencapsulation, neosomes, lipid nanoparticles, nanotubes, liposomes, and others. Using microcapsules to regulate the API release rate lowers the frequency of dose. This could be a drawback compared to microsponges when the wall bursts and releases all of the API contained in the microcapsules. Liposomes are spherical vesicles that contain a phospholipid bilayer and are employed as carriers of nucleic acids, peptides, and a variety of medications. Liposomes show stability-related issues, but microsponges are stable at high temperatures and across a pH range of 1 to 11. Preservatives are necessary for liposomes but not for microsponges. The entrapment efficiency of liposomes is roughly 30%, but microsponges have an approximate 50%–60% efficiency. As a result, liposomes exhibit lower payload than microsponges[5], are more complex to make, more costly economically, lack microbiological stability, and have less chemical stability.

2.3.3. Advantages over Ointments

Ointments have low penetration efficiency, hence a large concentration of API was needed to achieve an effective therapeutic effect. High concentrations create oily, sticky, and unsightly side effects such allergic responses and irritation. They also make patients less likely to comply with treatment recommendations. Their unpleasant smell and uncontrollably evaporating active component are other drawbacks. With certain formulations, drug-vehicle incompatibilities may occur. Microsponges delivery systems, as opposed to ointments, provide better penetration with less transdermal penetration into the body, maximizing the retention period on the surface of the skin or within the epidermis or dermis[5].

3.0 FEATURES OF ACTIVES ENTRAPPED IN MDS

Most liquid or soluble ingredients can be entrapped in the particles. Actives that can be entrapped in microsponges must meet following requirements:

- It should be either fully miscible in monomer or capable of being made miscible by addition of small amount of a water immiscible solvent. It should be water immiscible or nearly only slightly soluble. □

- It should be inert to monomers and should not increase viscosity of mixture during formulation.
- It should be stable in contact with polymerization catalyst and conditions of polymerization[11] .
- Than 10 to 12% w/w microsponges must be incorporated into the vehicle. Otherwise, the vehicle will deplete the microsponges before the application[8] .
- The spherical structure of microsponges should non- collapsible[12].

4.0 DRUG RELEASE MECHANISM OF MICROSPONGES

After applying the completed dosage form to the skin, the active substances in the vehicle will soak into the skin, depleting it and causing it to become unsaturated, upsetting the equilibrium. As a result, the active substances from the microsponge particle will begin to seep into the vehicle and then into the skin, where they will remain until the vehicle is either dried out or absorbed. Long-lasting release of the active substances to the skin is ensured by the retention of microsponge particles on the stratum corneum surface. When combining the final dosage form, if the active components are excessively soluble in the chosen vehicle, the products won't offer the intended slow release effects.It is typically advised to maximize the solubility of the active components in the vehicle for the conventional system.The product should be formulated with some free and some entrapped active ingredients so that the vehicle is presaturated in order to prevent undesired premature leaching of the active chemicals from the micro sponge polymer. The partition coefficient of the active chemicals between the polymer and the vehicle, as well as a few other parameters that describe the release, will determine how quickly the active ingredients are released.Examples of these are surface area and primarily, mean pore diameter. Release can be controlled through diffusion or other triggers such as friction, moisture, temperature or pH[3] .

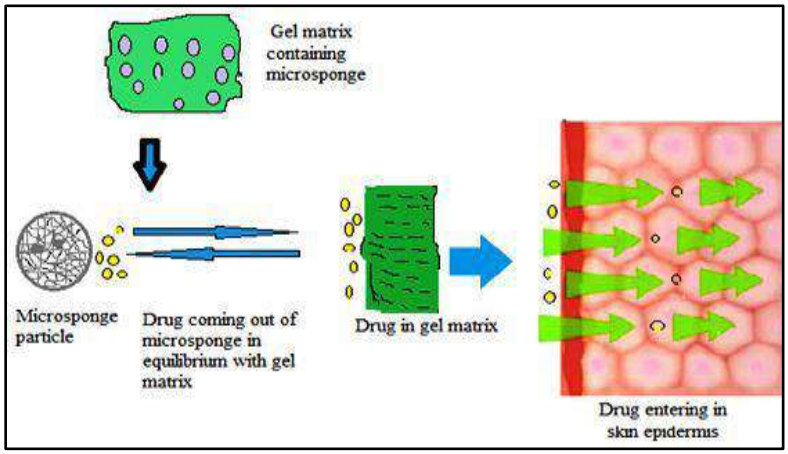

Fig.3 Mechanisms of drug release from Microsponges for topical application

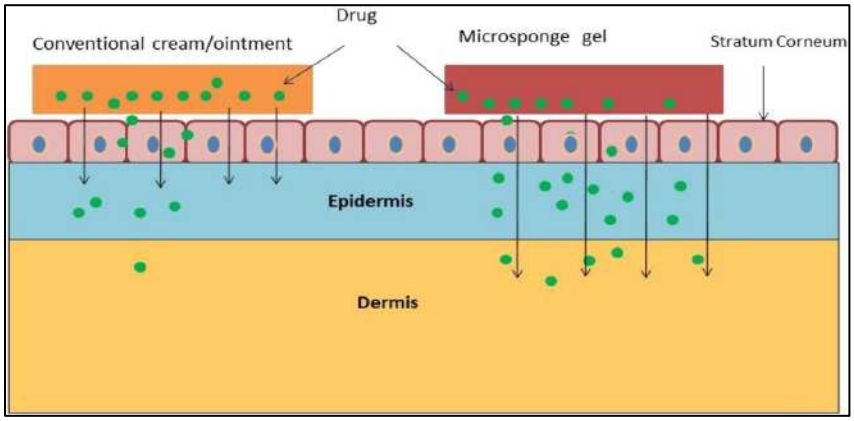

Fig.4: Systematic representation of microsponges and conventional topical preparation (Microsponges provides improved permeation through stratum corneum and prolongs retention in epidermis and dermis layer.)

4.1. The Programmable release of actives from microsponges

4.1.1. Pressure triggered release

When microsponge is rubbed or compressed, the medication that is trapped inside releases. The size, number of pores on the sponge, and resilience (viscoelastic characteristics) of the micro-sponge all affect how much is released. The softening effect of mineral oil including micro sponge was significantly greater than that of mineral oil containing microcapsules.For the micro sponge systems, the emollience duration was likewise significantly longer[11].

4.1.2. Temperature-triggered release

Similar to sunscreens, the active chemicals put into microsponges are viscous when stored or at room temperature and do not fully diffuse out of the microsphere. Therefore, when the skin is applied by rubbing or by raising the temperature, the viscosity of the active substance is reduced, allowing the skin to absorb it more forcefully. The skin's temperature can occasionally be raised to improve the drug's mobility. It is simple to control the drug's release simply adjusting the temperature[8].

4.1.3. pH-triggered release

The pH-dependent polymers are coated on the microsponge in this method. These polymers either grew or leached out of the microsponges depending on the pH. The medication was released from the microsponges following the leaching of a pH-dependent polymer. The application of medication delivery to site-specific delivery is increased when the microsponge is coated. The release rises from 0% to 80% when the pH is raised from 3 to 8. Therefore, pH can be changed to speed up the drug's release[13].

4.1.4. Solubility triggered release

Water-soluble substances, such as antiseptics and deodorants, only release their active constituents when an aqueous medium is present in the microsponge. The external medium's capacity to dissolve the active ingredients determines how quickly the medicine releases from the microsponge.Diffusion may also cause the release, but it must take into account the ingredient's partition coefficient between the microsponges and the external system.

5.0. METHODS OF PREPARATION OF MICROSPONGES:

Initially, drug loading in microsponges is mainly taken place in two ways depending upon the physicochemical properties of a drug to be loaded. If the drug is consistently an inert nonpolar material which will generate the porous structure then, it is known as the porogen. A Porogen drug neither hinders the polymerization process nor become activated and is stable to free radicals

entrapped within a one-step process (liquid-liquid suspension polymerization). Microsponges are suitably prepared by the following methods:

A. Liquid-liquid suspension polymerization

In liquid-liquid systems, the suspension polymerization process is used to create the porous microspheres. This approach involves dispersing the immiscible monomers in the aqueous phases, which include surfactant and suspending agents to help form the suspension, after they have been dissolved with the active components in a suitable solvent monomer. Afterwards, a catalyst is added, the temperature is raised, or the polymerization is exposed to radiation. The creation of a reservoir-type system with a spherical structure is furthered by the polymerization process. The solvent is removed from the spherically-structured porous microspheres, or microsponges, following the polymerization process.

Step 1: Selection of monomer as well as a combination of monomers.

Step 2: Formation of chain monomers as polymerization starts.

Step 3: Formations of ladders as a result of cross-linking between chain monomers. Step 4: Folding of monomer ladder to form spherical particles.

Step 5: Agglomeration of microspheres leads to the production of bunches of microspheres.

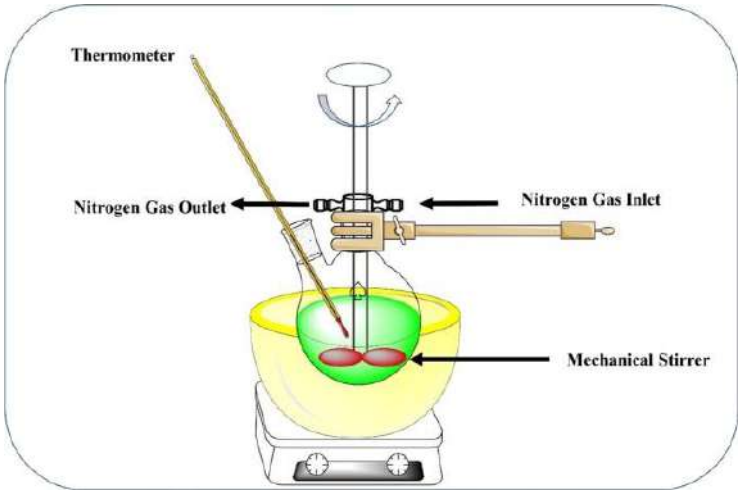

Figure 4: Microsponge preparation of liquid liquid suspension polymerization

B. The quasi-emulsion solvent diffusion method

This method starts with a premade polymer and works its way down. In this technique, an interior phase and an exterior phase that resembles emulsions are formed into a quasi-emulsion. With vigorous stirring, the external phase consisting of the aqueous polyvinyl alcohol (PVA) solution was combined with the interior phase of a drug-polymer solution prepared in a volatile solvent such as ethanol, acetone, or dichloromethane. To enable flexibility, a suitable quantity of triethyl citrate (TEC) was added. Quasi-emulsion globules are distinct emulsion globules that form as a result of stirring. After that, the solvent is removed from these globules to create stiff, insoluble microparticles, or microsponges. Once the mixture has been sufficiently stirred, the microsponges are separated using filtering. After that, the microsponges are dried.The idea is that water and organic solvent counter-diffuse into and out of the finely dispersed droplets of the drug's polymeric solution (the dispersed phase) to solidify them in the aqueous phase. the aqueous phase that has diffused within the droplets.The aqueous phase that has diffused within the droplets. The drug and polymer solubility were reduced by the diffused aqueous phase in the droplets, which led to their co-precipitation. Further solidification was achieved through the organic phase's ongoing diffusion, resulting in matrix-type porous

microspheres.This method has two advantages over the liquid-liquid suspension polymerization method: less exposure of the medication to ambient conditions and low solvent residues in the result due to the solvent's extraction due to its volatile nature or its solubility in aqueous media.

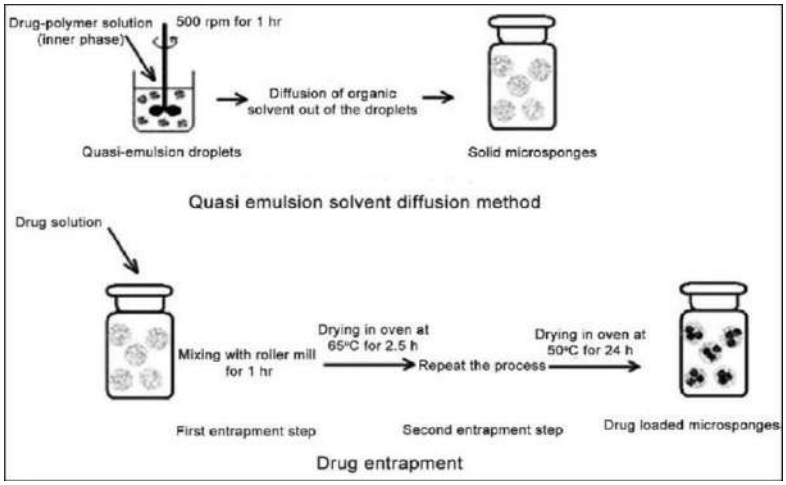

Figure 5: Quasi-Emulsion solvent diffusion method

C. Multiple-emulsion Solvent Diffusion (Water in oil in water (w/o/w) emulsion solvent diffusion) method:

To create biodegradable porous microparticles, a new method was created.

Using this technique, an organic polymeric solution was mixed with an internal aqueous phase that contained an emulsifying agent such as span, polyethyleneimine, and stearyl amine. To create a double emulsion[6], this w/o emulsion was then again dispersed in an external aqueous phase containing PVA.

Advantages:

1. The entrapment of both water soluble and water insoluble drugs.
2. This method can be used for entrapment of thermolabile substances like proteins[6].

D. Lyophilization

By using the gelation procedure, a novel method is employed to transform the microparticles into porous microparticles. Using this method, the microparticles were lyophilized after being incubated in a solution of chitosan hydrochloric acid. The quick removal of the solvent causes the microparticles to become porous.

Advantage:

This method is quick and rapid.

Disadvantage:

Due to rapid elimination of solvent, there may be chances of broken or shrunken microparticles are produced.

E. Ultrasound-Assisted Production

By altering the liquid-liquid suspension polymerization process, this technique was created. The cross-linking agent diphenyl carbonate and the monomer beta-cyclodextrin (BCD) are used in the manufacture of the microsponges. Heating and sonicating the reaction mixture allowed for the control of the microparticles' size. After the reaction mixture was allowed to cool, the resulting product was ground into rough particles and cleaned with ethanol and distilled water. The crosslinked β-CD (BCD) microparticles are porous and can be effectively used as carriers for drug loading.

Disadvantage:

This technique has the limitation of entrapment of residues of the cross-linking agents that can be potentially toxic[6].

6.0. EVALUATION PARAMETERS OF MICROSPONGES

1. Particle size determination
2. Morphology and Surface Topography of Microsponges
3. Determination of Loading Efficiency and Production Yield
4. Resiliency (viscoelastic properties)
5.Characterization of Pore structure (pore volume and diameter)
6.Compatibility studies
7. Kinetics of drug release
8. Dissolution Studies,
9. Determination of true density
10.Drug release from semisolid dosage form and Drug Disposition studies
11.In-vitro diffusion studies.

6.1. Particle size determination

The texture and stability of the formulation are significantly influenced by the size of the particles. By adjusting the size of the particles during polymerization, it is possible to produce free-flowing powders with exquisite aesthetic qualities.The examination of the particle size of loaded and unloaded micro sponges is done using laser light diffractometry.

For any formulation, the values (d50) can be stated as the mean size range. To investigate the impact of particle size on drug release, the cumulative percentage of drug released from microsponges with varying particle sizes will be plotted versus time. An optical microscope is also used to measure the particle size. A stage micrometer was installed in the microscope in order to calibrate the ocular micrometer. The figures for the mean particle size range were provided.

One division of stage micrometer = 0.01mm = 10µm

$$C = SM \times 10 / EM$$

where,

C = correction factor

SM = reading of stage micrometer which coincides with reading of eyepiece Micrometer.

The particle diameter of around 100 particles was measured. The average particle size was determined using the following formula:

$$D\ mean = \sum nd / \sum n$$

Where,

n = number of microsponges observed

d = mean size range

Every formulation was examined three times, and the mean of the three experiments was determined. Particles bigger than 30µm have the potential to produce a gritty feeling; therefore, for usage in the final topical formulation, particles between 10 and 25µm are preferred.

6.2. Morphology and Surface Topography of Microsponges

Numerous methods, including Photon Correlation Spectroscopy (PCS), Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), and Freez Fracture Microscopy (FFM), have been employed to study morphology and surface topography. SEM is frequently used to examine the surface morphology of prepared microsponges that have been coated with gold or palladium at room temperature in an argon environment. An image of a fragmented micro sponge particle's ultrastructure can likewise be obtained using SEM.

6.3. Determination of Loading Efficiency and Production Yield

The High Performance Liquid Chromatography (HPLC) method was used to ascertain the drug content of the microsponges. One milliliter of methanol was used to dissolve a drug sample containing ten milligrams of microsponges. The calibration curve was used to determine the drug content, which was then stated as loading efficiency (%), which may be computed using the formula below:

$$Drug\ content = \frac{Amount\ of\ drug\ in\ microsponges}{Amount\ of\ Microsponges} \times 100$$

The production yield of the microsponges can be determined by calculating accurately the initial weight of the microsponges and the final weight of the micro sponge obtained.

$$\text{Production yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}} \times 100$$

6.4. Resiliency (Viscoelastic properties)

Microsponges' resilience, or viscoelastic qualities, can be changed to create bead lets, or spherical, freely flowing grains, that are either softer or stiffer according on what the final composition requires. Elevated cross-linking typically results in a slower rate of release. As a result, the study and optimization of microsponges' resilience in accordance with the requirements will take release into account as a function of cross-linking over time.

6.5. Characterization of pore structure (pore volume and pore diameter)

The diameter and volume of the pores play a significant influence in regulating the active ingredients' duration and intensity of action. Mercury intrusion porosimetry can be used to evaluate the porosity parameters of microsponges, including bulk and apparent density, pore size distribution, total pore surface area, average pore diameters, shape and morphology of the pores, and intrusion extrusion isotherms. Plotting incremental intrusion volumes versus pore diameters that corresponded to pore size distributions is possible. It is possible to compute the microsponges' pore diameter.

$$d_p = -\frac{4 \cdot \sigma}{p} \cos\theta$$

by using Washburn equation:

Here,

D is the pore diameter (μm),

γ is the surface tension of mercury (485 dyne cm−1),

θ is the contact angle (130o), P is the pressure (psia).

6.6. Compatibility studies

Fourier Transform Infrared Spectroscopy (FT-IR) and thin layer chromatography (TLC) can be used to study a drug's compatibility with reaction adjuncts. Differential scanning calorimetry and powder X-ray diffraction (XRD) can be used to examine how polymerization affects the drug's crystallinity (DSC). For DSC, five milligram samples can be precisely weighed into aluminum pans, sealed, and heated at a rate of fifteen degrees Celsius per minute within a temperature range of twenty-five to forty-three degrees Celsius in a nitrogen atmosphere.

6.7. Kinetics of drug release

To determine the drug release mechanism and to compare the release profile differences among microsponges, the drug released amount versus time was used. The release data were analysed with the following mathematical models:

$$\mathbf{Q = K1\ t^{n}}$$

OR

$$\mathbf{\log Q = \log K1 + n \log t}$$

Where, Q is the amount of the released at time (t), n is a diffusion exponent which indicates the release mechanism,

k1 is a constant characteristic of the drug–polymer interaction.

From the slope and intercept of the plot of log Q versus log t, kinetic parameters n and k1 were calculated.

For comparison purposes, the data was also subjected to equation which may be considered a simple, Higuchi type equation:

$$\mathbf{Q = K2\ t\ 0.5 + C}$$

Above equation for release data dependent on the square root of time, would give a straightline release profile.

Where, k2 presented as a root time dissolution rate constant.

C is a constant.

6.8. Dissolution studies

A modified basket made of 5µm stainless steel mesh can be used with the dissolution apparatus (USP XXIII) to study the dissolution profile of microsponges. There is a 150 rpm rotational speed. In order to guarantee sink conditions, the dissolution medium is chosen while taking the actives' solubility into account. At different periods, samples from the dissolution medium can be examined using an appropriate analytical technique.

6.9. Determination of true density

The true density of microparticles is measured using an ultra-pycnometer under helium gas and is calculated from a mean of repeated determinations.

6.10. Drug release from semisolid dosage form and Drug Disposition studies

The Franz-type static diffusion cells are responsible for releasing the drug from the semi-solid dosage forms. The skin's epidermal side was exposed to the outside environment in this instance. The skin's surface was maintained facing the receptor solution. A 20 mL phosphate buffer pH 5.8 reservoir compartment was placed in a thermostate at 32±0.5°C and agitated at 600 rpm. Before the sample was applied, the skin was soaked for one hour with the diffusion medium. A sample weighing 200 mg was administered to the donor compartment. After 4, 8, 16, and 24 hours, the diffusion cell was disassembled to determine the amount of medication deposited in the skin. The medicine that was on the skin's surface was removed with caution, and distilled water[19] was used to clean it.

6.11. In-vitro diffusion studies

The prepared micro sponge gel was subjected to in vitro diffusion studies in a Keshary–Chien diffusion cell using a cellophane membrane. The receptor compartment was created using 100 ml of phosphate buffer, and 500 mg of gel containing 10 mg of drug was uniformly spread on the membrane. The temperature was maintained at 37±0.50C and the donor compartment was kept in contact with a receptor compartment. At predetermined intervals, the receptor side solution was stirred by externally driven Teflon coated magnetic bars, and 5 ml of solution was pipetted out of the receptor compartment and immediately replaced with fresh 5 ml phosphate buffer. The drug concentration on the receptor fluid was measured spectrophotometrically against the appropriate blank.

7.0 THERAPEUTIC APPLICATIONS OF MDDS

Research is being done on microsponges for a range of medicinal uses. It offers a cutting-edge system of appropriate carriers for medicinal agents and has the ability to alter and regulate the medications' release. Microsponges are rapidly expanding into new areas of use. These include topical formulations for the treatment of a wide range of skin conditions, as well as oral formulations that release medication at specific target regions at predetermined rates. Advances in microsponges, such as nano sponges, nanoferrosponges, and porous microbeads, have been observed recently. β-Cyclodextrin nano sponges are made by altering the preparatory stages. They can be used to deliver a variety of medications, such as hydrophilic and hydrophobic medications, topically or orally, as well as gaseous or volatilized particles, malignant cell treatment, and delivery of siRNA and RNA.

7.1. Microsponges in psoriasis

Psoriasis is a long-term, autoimmune skin condition that causes scaly, itchy, and disfiguring skin sores. It shows up as hyperproliferation, thicker epidermis, and altered keratinocyte differentiation. It lowers the afflicted person's quality of life. The potential of microsponges to treat psoriasis has been investigated.For instance, psoriasis and other inflammatory and pruritic conditions are treated with metastasone furoate. Emulsion solvent diffusion was used to create microsponges. Biphasic release with an initial burst effect was evident in the release profiles. Seven formulations demonstrating a 29%–36% drug release in the first hour and a 78%–95% cumulative release after eight hours were produced.

7.2. Microsponges in arthritis

Diclofenac is primarily used as an NSAID to treat the pain and swelling brought on by musculoskeletal conditions like arthritis, however taking it orally might cause issues like first-pass metabolism and stomach discomfort. Therefore, the aforementioned issues can be resolved using topical formulations containing diclofenac microsponges. The quasi-emulsion solvent diffusion method was used to manufacture the diclofenac diethyl amine microsponges gel. According to research on drug release, gels released 81.11% of the drug for up to four hours, but gels based on microsponges released the drug for up to eight hours.

7.3. Microsponges formulation for antifungal

Terbinafine hydrochloride microsponges as an antifungal agent. Drug-loaded microsponges-based gel was tested in vitro and contrasted with drug-loaded plain gel in these investigations. The drug-laden plain gel exhibited 96.65% drug release for up to six hours, but the gel loaded with microsponges had the best sustained drug release for almost ten hours. In contrast to ordinary gels, terbinafine hydrochloride loaded microsponges gels demonstrated prolonged drug release.

Furthermore, oxiconazole nitrate microsponges were created utilizing the quasi-emulsion solvent diffusion method and subsequently added to the gel. Another antifungal drug with poor aqueous solubility, side effects, and adverse reactions is oxiconazole nitrate.

7.4. Microsponges in skin infections

In addition, microsponges are used as creams or gels to treat a variety of skin conditions, including atopic dermatitis and eczema. An antibiotic called mupirocin is applied topically to treat skin infections. Emulgel base was combined with mulirocin microsponges, which were created using the emulsion solvent diffusion process to provide a long-lasting protection against skin infections. The gel microsponges showed drug release for up to 10 hours, but the ointment showed drug release for up to 4 hours.

7.5. Microsponges in acne

One of the most common skin conditions, acne is linked to skin inflammation. One of the most often used medications for treating acne is benzoyl peroxide. Benzoyl peroxide microsponges were made to regulate the amount of benzoyl peroxide applied to the skin. Studies on drug release have revealed that drug release peaked in four hours and then steadied for the following seven. This could be because there was a nonencapsulated drug present, and when it released entirely, the release of the entrapped drug became constant.

7.6. Microsponges in skin protection

Sunscreens shield the skin from UV radiation, which causes sunburns. Even at elevated concentrations, the formulation of the microsponges offers long-lasting product efficacy with enhanced protection against sunburn and sun-related injuries as well as reduced irritancy and sensitization. Microsponges, a topical delivery system for the broad-spectrum sunscreen ingredient oxybenzone, can be developed to boost

the effect. They used the solvent diffusion method of quasi-emulsion to formulate it. The marketed lotion had an SPF of 20 whereas the microsponges gel had an SPF of 25, which may have been caused by the delayed drug release from the microsponges gel, demonstrating extended oxybenzone retention[13].

8.0 FUTURE PERSPECTIVE

With unique properties like enhanced product performance and elegance, extended release, improved drug release profile, decreased irritation, and improved physical, chemical, and thermal stability that make it flexible to develop novel product forms, the microsponges drug delivery system holds great promise in a variety of pharmaceutical applications in the near future. The true obstacle facing MDS going forward is creating a delivery mechanism for oral peptide delivery using different polymer ratios. The safe delivery of the active ingredient is made possible by the use of bioerodible and biodegradable polymers in the medication delivery process. Since these porous systems have also been investigated for the pulmonary route of drug administration, it is evident that this technology can demonstrate excellent drug release even in the limited of the dissolution fluid thus colon is an effective site for targeting for drug release. It is also necessary to design these carriers for parenteral and pulmonary drug administration routes, among others. These particles can be utilized for stem cell culture and cellular regeneration in the body because they can also be used as the cell culture medium. These carrier systems have also found use in cosmetics because of their elegance. The researchers were inspired to create further porous microspheres, nano sponges, nanoferrosponges, and porous microbeads by these distinctive characteristics. These advancements made it possible for researchers to apply them differently. These formulation innovations create new avenues for medication administration.

CONCLUSION:

With MDS being a highly competitive and quickly developing field of study, more and more studies are being conducted to maximize the therapy's effectiveness and cost-efficiency. This solitaire method, which is also utilized for oral and biopharmaceutical drug delivery, uses microporous beads laden with the active agent to distribute topical drugs in a regulated manner. The health care system is greatly impacted by microsponge delivery systems that can precisely regulate release rates or target specific body sites for drug delivery. In addition to releasing its active ingredient on a timed basis, a microsponge delivery system can also release it in reaction to other stimuli. As a result, research is needed in the extremely new and highly promising subject of microsponge.

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