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Mini Review

Microsponge Drug Delivery Systems: Formulation Approaches, Characterization Techniques and Emerging Applications

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ABSTRACT

Microsponges are advanced drug delivery carriers composed of highly porous, cross-linked polymeric microspheres with a spherical structure, typically ranging from 5 to 300 µm in diameter. These systems have gained considerable attention due to their ability to provide controlled and sustained release of poorly water-soluble drugs. By enhancing drug stability, minimizing adverse effects, and modifying drug release patterns, microsponges serve as an effective and versatile delivery platform. The porous structure of microsponges enables encapsulation of a wide range of active pharmaceutical ingredients, which can subsequently be incorporated into various dosage forms including gels, creams, capsules, powders, and liquid formulations. This review highlights the fundamental aspects of Microsponge Delivery Systems (MDS), including their unique properties, advantages, preparation techniques such as liquid–liquid suspension polymerization and quasi-emulsion solvent diffusion, and drug release mechanisms. In addition, the article discusses important characterization parameters including particle size and distribution, surface morphology, production yield, drug loading efficiency, compatibility studies, true density, and in-vitro drug release evaluation. Furthermore, the applications of MDS in oral delivery, topical therapy, cosmetics, bone regeneration, and tissue engineering are also summarized. (1)

INTRODUCTION

The drug delivery technology landscape has become highly competitive and rapidly evolving. More and more developments in delivery systems are being integrated to optimize the efficacy and cost-effectiveness of the therapy. New classes of pharmaceuticals, biopharmaceuticals (peptides, proteins and DNA-based therapeutics) are fuelling the rapid evolution of drug delivery technology. These new drugs typically cannot be effectively delivered by conventional mean. Drug delivery systems (DDS) that can precisely control the release rates or target drugs to a specific body site have had an enormous impact on the health care system. (1)

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In recent years there is increasing demand in cosmetic and skin care, extensive usage of substances like α-hydroxy acids and vitamins in topical solutions, which can offer advantages, particularly in aging or photodamaged skin, has encouraged consumers growing interest in skin care and treatment goods. Despite its benefits, these substances may cause irritation, which manifests as burning, stinging, or redness and is especially common in people with sensitive skin. Acknowledging this issue, the formulators have tried to address it using one of the two approaches. They have decreased the concentration of these components, but their effectiveness has been compromised in the process. Additionally, the vehicle has been altered to make the substance more skin-compatible or emollient. This strategy frequently also lessens the positive impacts of formulations. Several predictable and dependable systems for systemic medications have been created within the category of transdermal delivery systems (TDS), which use the skin as a portal of entry. It has enhanced the safety and effectiveness of numerous medications that might be more effectively applied topically. However, materials whose ultimate goal is the skin itself cannot be delivered using TDS. Research on the controlled release of pharmaceuticals onto the epidermis with the guarantee that the medication stays mostly localized and does not significantly penetrate the systemic circulation. This is research gap showing significant need for another novel approach to deliver medication systemically by crossing barriers on epithelium of skin.

The most practical and widely used method of administering drugs is the oral route. Drugs with a short half-life and easy gastric absorption are quickly removed from the bloodstream. Oral controlled release formulations, which release medication gradually into the gastrointestinal tract and aid in maintaining a steady drug concentration in the serum for extended periods of time, have been created to avoid these issues. The oral method of medicine delivery is widely accepted. Up to 50–60% of oral solid dose forms are popular due to self-medication, pain avoidance, regular, simple, and appropriate administration with exact amount, and most importantly, patient compliance. Tablets and capsules are the most popular solid dosage forms; they can be used in a variety of innovative drug delivery systems, including nanoparticles, microparticles, microspheres, nanospheres, and microsponges.[2]

Defining Microsponges

Highly cross-linked, porous polymeric microspheres known as Micro-sponge Delivery Systems (MDS) are capable of capturing a wide variety of active substances and releasing them gradually in response to stimuli. This approach was previously suggested to improve the effectiveness of medications. Microporous beads filled with an active ingredient make up this novel technique for controlled release.[2]

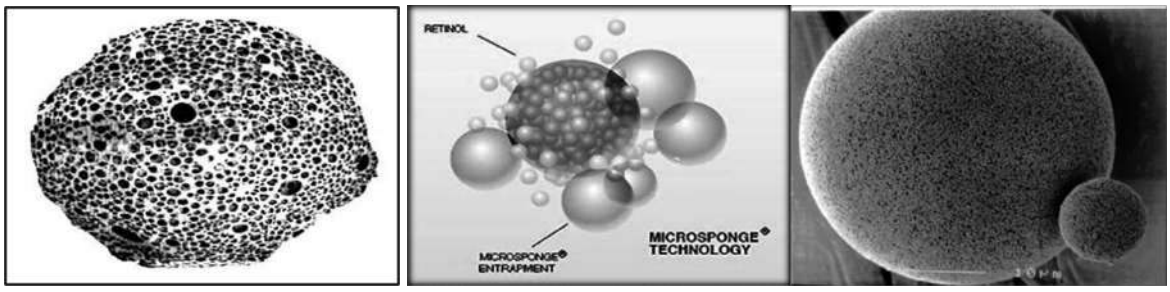


Fig. Porous structure Of Microsponges.

The microsponge system can prevent excessive drug accumulation in the dermis and epidermis. Without sacrificing the efficacy of strong drugs, the microsponge system may be able to significantly reduce the irritation they produce. The unfilled spheres are subsequently eliminated by the next washing. The microsponge delivery technology satisfies these requirements and has created a new generation of inventive, highly efficient, and well-tolerated goods. These products, which are typically sold to customers in conventional forms like creams, gels, or lotions, have a relatively high concentration of active ingredients. Numerous active substances, including emollients, sunscreen, essential oils, perfumes, and anti-inflammatory compounds, can be captured by microsponges. The microsponges' diameters might vary, often falling between 5 and 300 µm., based on the level of smoothness or after-feel needed for the final recipe. A typical 25 µm sphere can contain up to 250000 pores and an interior pore structure similar to 10 ft in length, yielding a total pore volume of around 1 ml/g, though the microsponge size may vary. As a result, each microsponge has a reservoir that can hold up to its own weight of active material.

Rationale Of Microsponge Drug Delivery:

- To overcome other innovative medication delivery systems:

I) **Microspheres:** Unable to regulate the drug's release rate. The medication inside the microspheres will be released after the outer coating burst.

II) **Liposomes**: They have drawbacks such as reduced drug entrapment, formulation preparation challenges, and limited chemical and microbiological stability, necessitating the use of preservatives.

III) **Nanomaterial**: They can readily enter the systemic circulation through inhalation, and they may also be absorbed through the skin, particularly if the skin is injured.

IV) **Lipid nanoparticles**: The majority of their advantages are limited to topical medication delivery.

- To improve stability.
- To make entrapment more effective.
- To lessen toxicity and irritation.
- To enhance Bioavailability and Efficacy.
- To achieve formulation flexibility.
- To avoid Microbial contamination as pores diameter small restricts entry of any Micro-organisms.
- To provide prolonged therapeutic benefit for drugs having short half-life.

Limitations [3]:

The preparation methods usually use organic solvents as porogens, which pose an environmental hazard, as some may be highly inflammable, posing a safety hazard. In some cases, the traces of residual monomers have been observed, which may be toxic and hazardous to health.

Selection criteria of drug in Microsponges delivery

Properties	Desired Characteristic
Molecular weight	Low to moderate
Solubility	Slightly Soluble
Log P	Moderate
Stability	High
Melting Point	<250 ° C
Polymer Compatibility	high

Volatility	Non volatile
Half life	Short (less than 2 hr)
Dose	Low
Therapeutic Index	Wide
Bioavailability	Moderate
Absorption	Predictable
Action Site	Localized/ Topical and controlled systemic

Characteristics of material to be entrapped [4]

- It should be either totally miscible in monomer as well as capable of being made miscible by adding of tiny amount of a water immiscible solvent.
- It should not make the mixture more viscous during formulation and should be inert to monomers.
- It should not collapse the spherical structure of the micro-sponges
- It should be stable in contact with the polymerization catalyst and during polymerization conditions
- It should be water immiscible or little soluble.

Components of Microsponge Formulation

1. **Drug:** drugs are typically chosen based on their stability and solubility characteristics. Most commonly, slightly water-insoluble drugs are preferred because they can be effectively entrapped within the porous matrix and released in a controlled manner. The drug should remain chemically stable during the preparation process, as exposure to solvents and stirring conditions may otherwise lead to degradation. Lower molecular weight drugs are generally more suitable, as they can diffuse more efficiently through the porous structure.
2. **Polymer[6][7]:** Polymers such as ethyl cellulose and different grades of Eudragit are widely used due to their hydrophobic nature and ability to form rigid, porous structures. These polymers are either insoluble or only slightly soluble in water which allows them to sustain drug release over an extended period. The physical characteristics of the polymer, including its molecular weight and permeability, play a crucial role in determining the final particle size, porosity, and drug release profile. A stronger and more hydrophobic polymer generally results in slower drug release, whereas a more permeable polymer may allow faster diffusion of the drug.
3. **Solvents[5]**: Organic solvents like dichloromethane, ethanol, or methanol are commonly used to dissolve both the drug and polymer, forming the internal phase of the system. These solvents are typically volatile and have low boiling points, which is important because they must evaporate during the preparation process. The evaporation of the solvent leads to the formation of a porous structure within the Microsponges particles.
4. **Surfactant and Emulsifying Agent[6][8]:** Substances such as polyvinyl alcohol or Tween 80 help reduce surface tension and maintain a stable emulsion during the preparation process. These compounds possess both hydrophilic and lipophilic properties, allowing them to interact with both the aqueous and organic phases. As a result, they prevent aggregation of particles and ensure uniform size distribution. The concentration of surfactant is particularly important, as higher concentrations tend to produce smaller and more uniform particles,

while insufficient amounts may lead to instability and clumping.

5. **Plasticizer[4]**: Plasticizers are added to improve the flexibility and mechanical properties of the polymer matrix. Compounds like triethyl citrate are commonly used for this purpose. Plasticizers are generally low molecular weight substances that integrate into the polymer structure and reduce its brittleness. This results in a more stable and elastic Microsponges system.

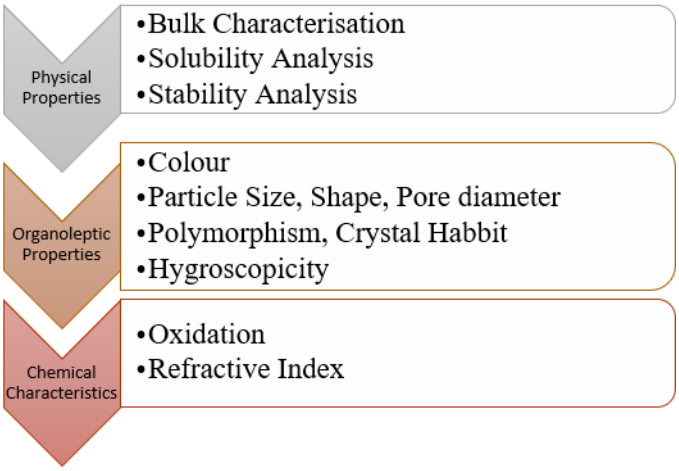
6. **Aqueous Phase[9]**: The aqueous phase, usually consisting of distilled water, acts as the continuous phase in which the emulsion is formed. It provides a medium for the dispersion of the internal phase and facilitates the solidification of the Microsponges particles. Proper stirring in the aqueous phase is essential to ensure the formation of spherical and uniformly distributed particles.

7. **Other Additives[10]:** Additives may be included depending on the intended dosage form. For example, Carbopol may be used when microsponges are incorporated into gels, while excipients like lactose or magnesium stearate may be added for tablet formulations. These additives generally do not participate directly in Microsponges formation but enhance the overall performance, stability, and applicability of the formulation.

METHODOLOGY

1. **Preformulation Studies [11]-**

Pre-formulation represents a vital step in the research and development of a new drug compound. This phase focuses on analysing the physical, chemical, and mechanical properties of the active pharmaceutical ingredient (API), both independently and in combination with excipients. The primary objective is to design a dosage form that ensures stability, safety, and therapeutic effectiveness



2. **Determination of calibration Curve:**

Calibration Curve is Obtained by Taking Solvent of suitable Wavelength as reference standard and drug. Graph is plotted against Wavelength Vs % Absorbance.

3. **Check Compatibility of drug with Polymer/Excipients using DSC or FT-IR.**

4. **Method of Preparation Of Microsponges [2,3]**

The drug's and polymer's solubility properties play a major role in the choice of encapsulating technique. The diffusion solvent method is a widely used technique for encasing water-insoluble medications in water-insoluble polymers. This technique can be easily carried out in the lab and has the potential to be scaled up to manage enormous amounts of water.

When creating a microencapsulation process, the chosen approach should ideally result.

- Higher encapsulation of the core material.

- High yields of microparticles free of extensive agglomeration.
- Ability to adjust in vitro release rates by changing process parameters to prepare microparticles with the desired in vivo release characteristics.
- A reproducible release profile from batch to batch.[4]

Various Polymers used in Microsponges formulation For different purpose such as Eudragit RS100, Carbapol, Ethyl Cellulose, forming cage like Structure and plasticizers Triethyl citrate for cross linking are added with API.

Quasi Emulsion Solvent Diffusion[12,13]

This Process Involves Two Steps:

I). Internal Phase Preparation

Drug+ Polymer added in volatile solvent like acetone, Ethanol/ Dichloromethane.

II). External Phase consist of aqueous solution Such as (PVA) with Stirring continuously. Add sufficient amount of Plasticizer eg. Triethyl citrate. Following emulsification, the liquid was constantly agitated for two hours to create distinct emulsion globules known as quasi-emulsion globules. The rigid microparticles (MSPs) separate from the mixture by filtering. The product clean and dry for 24 hours at 40 °C in a hot air oven.

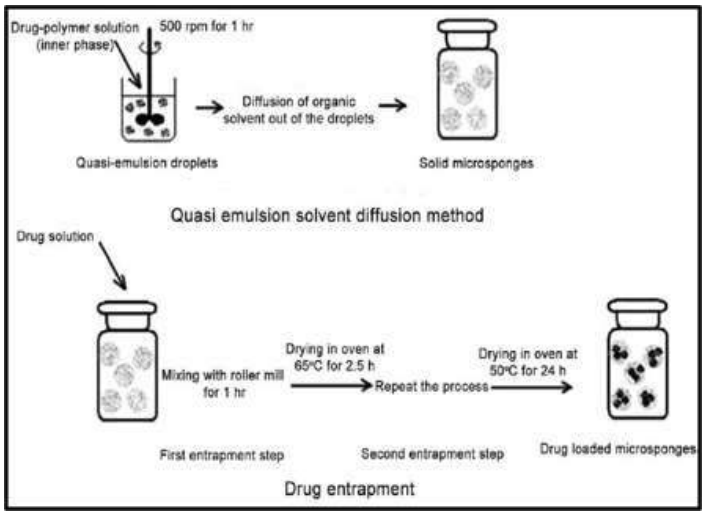


Fig. Quasi Emulsion solvent diffusion method

Liquid Liquid Suspension Polymerisation[14]

The preparation involves dissolving the monomers and active ingredients in an appropriate solvent solution before dispersing them in the aqueous phase (surfactant, suspending agent). After that, a catalyst is added or the temperature is raised to start the polymerization. A reservoir-like system that opens at the surface through pores. Sometimes the pore network is formed during the polymerization process using an inert solvent that is entirely miscible with monomer but immiscible with water. The solvent is removed from the porous microspheres following polymerization. When Drug is sensitive to Polymerization Quasi emulsion solvent diffusion Method is used.

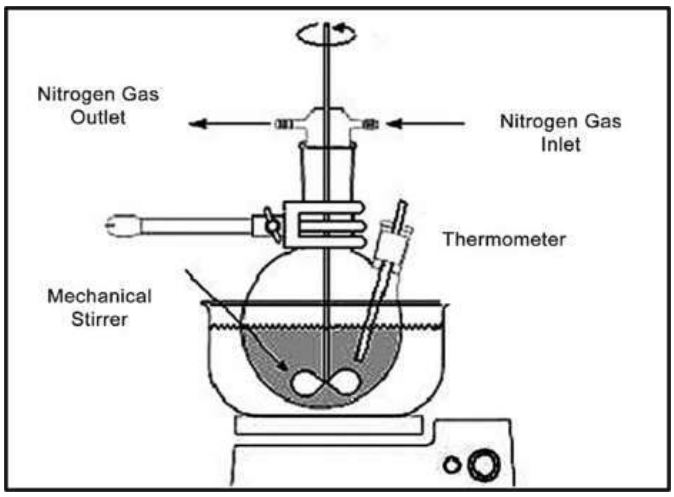
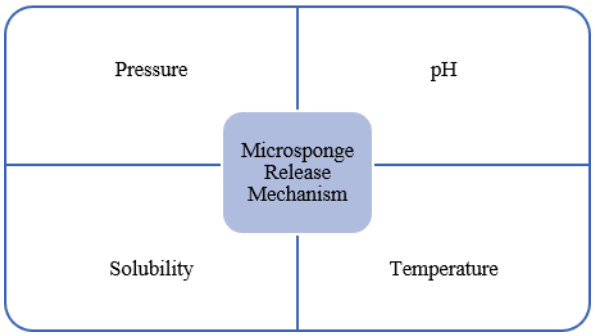


Fig. Liquid Liquid Suspension Polymerisation

Microsponge Release Mechanism[15]



Microsponge Release Its Product upon triggering Mechanism such as Rubbing, Change in the pH, Temperature may increase pressure on pores and release Medicament at controlled manner.

Characterization of microsponges

1. **Particle size and size distribution** [16]

Particle size and size distribution are evaluated using either an optical microscope or an electron microscope. This is an extremely crucial step, as the size of the particles greatly affects the texture of the formulation and its stability. Free flowing powders with fine aesthetic attributes are possible to obtain by controlling the size of particles during polymerization. Particle size analysis of loaded and unloaded Microsponges can be performed by laser light diffractometry or any other suitable method. The values (d50) can be expressed for all formulations as mean size range. Cumulative percentage drug release from Microsponges of different particle size will be plotted against time to study effect of particle size on drug release.

2. **Morphology and Surface topography of SPM** [17]

For morphology and surface topography, various techniques have been used like photon correlation spectroscopy (PCS), Scanning electron microscopy (SEM), transmission electron microscopy (TEM) etc. SEM is used widely for which prepared Microsponges are coated with gold–palladium under an argon atmosphere at room temperature and then the surface morphology of the Microsponges is studied.

3. **Determination of loading efficiency and production yield** [18,23,27]

% loading efficiency =

$$\frac{\text{Actual drug content in microsponges}}{\text{Theoretical drug content}} \times 100$$

The production yield of the microparticles can be determined by calculating accurately the initial weight of the raw materials and the last weight of the SPM obtained.

%Production yield =

$$\frac{\text{Production yield}}{\text{Theoretical mass (polymer + drug)}} \times 100$$

4. Determination of true density[19,20]

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

5. Compatibility studies(21,22)

The drug-excipients compatibility studies are carried out in order to ensure that there is no inadvertent reaction between the two when formulated into a dosage form. These studies are commonly carried out by recording the differential scanning Calorimetry (DSC) of the chemicals viz., API and excipients individually and also together and checking for any addition or deletion of any peaks or troughs. For DSC approximately 5 mg samples can be accurately weighed into aluminium pans and sealed and can be run at a heating rate of 15oC/min over a temperature range 25–430ºC in atmosphere of nitrogen. Infrared (IR) spectroscopy can also reveal the incompatibilities between the chemical moieties. Compatibility of drug with reaction adjuncts can also be studied by thin layer chromatography (TLC) and FT-IR. Effect of polymerization on crystallinity of the drug can be studied by powder X-ray diffraction (XRD) and Differential Scanning Colorimetry (DSC).

6. Polymer/ Monomer composition [23,24]

Factors such as particle size, drug loading, and polymer composition govern the drug release from Microsponges. Polymer composition of the Microsponges Drug Delivery system can affect partition coefficient of the entrapped drug between the vehicle and the Microsponges system and hence have direct influence on the release rate of entrapped drug. Release of drug from Microsponge systems of different polymer compositions can be studied by plotting cumulative % drug release against time. Release rate and total amount of drug released from the system composed of methyl methacrylate/ ethylene glycol dimethacrylate is slower than styrene/divinyl benzene system. Selection of monomer is dictated both by characteristics of active ingredient ultimately to be entrapped and by the vehicle into which it will be dispersed. Polymers with varying electrical charges or degrees of hydrophobicity or lipophilicity may be prepared to provide flexibility in the release of active ingredients. Various monomer combinations will be screened for their suitability with the drugs by studying their drug release profile.

7. Resiliency [25]

Resiliency (viscoelastic properties) of Microsponges can be modified to produce beadlets that is softer or firmer according to the needs of the final formulation. Increased cross-linking tends to slow down the rate of release. Hence resiliency of Microsponges is studied and optimized as per the requirement by considering release as a function of cross linking with time.

8. Drug Release [27,28,29]

Dissolution profile of Microsponges can be studied by use of dissolution apparatus USP XXIII with a modified basket consisted of 5µm stainless steel mesh. The speed of the rotation is 150 rpm. The dissolution medium is selected while considering solubility of actives to ensure sink conditions. Samples from the dissolution medium can be analyzed by suitable analytical method at various intervals.

Safety Considerations [30]

Safety studies of microsponges can be confirmed by-

I) Allergenicity in guinea pigs

II) Eye irritation studies in rabbits

III) Mutagenicity in bacteria

IV) Oral toxicity studies in rats

V) Skin irritation studies in rabbits.

Limitations[2]

Use of organic solvents poses threats, such as toxicity and flammability. Traces of residual monomers in bottom- up approach can be toxic and dangerous to health. But these limitations can be overcome by proper quality control measures coupled with optimization and standardization of procedures e. g, post manufacture washing.

Microsponge delivery systems are used to enhance the safety, effectiveness and aesthetic quality of topical prescription, over-the-counter and personal care products. Microsponges can be used in variety of applications. It is used mostly for topical and recently for oral administration. Several patents have reported that it can be used as excipients due to its high loading capacity and sustained release ability. It offers the formulator a range of alternatives to develop drug and cosmetic products. Microsponges are designed to deliver a pharmaceutical active ingredient efficiently at the minimum dose and also to enhance stability, reduce side effects and modify drug release. Over-the-counter products that incorporate microsponge drug delivery system include numerous moisturizers, specialized rejuvenative products, and sunscreens.(9)

Recent Marketed Formulations for cosmetics & Dermatology

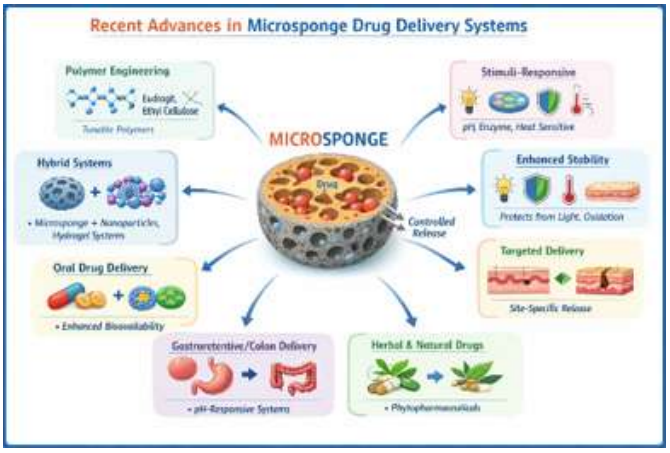
Application Of Microsponges [31]

Sr. No.	Product Name	Active Ingredient(s)	Manufacturer	Dosage Form	Application
1	Retin-A Micro	Tretinoin (0.04%, 0.1%)	Ortho Dermatologics / Johnson & Johnson	Gel	Acne, anti-aging, wrinkle reduction
2	NeoBenz® Micro	Benzoyl peroxide	Intendis Inc.	Gel / Cream	Acne (antibacterial, keratolytic)
3	Salicylic Acid Peel 30	30% Salicylic acid	Biomedic	Peel solution	Exfoliation, acne, keratolysis
4	Ultra Guard	Dimethicone	Scott Paper Company	Cream	Diaper rash protection, skin barrier
5	Retinol 15 Night Cream	Retinol	Biomedic / Sothys	Cream	Anti-aging, wrinkle reduction
6	EpiQuin Micro	Hydroquinone + Retinol	SkinMedica Inc.	Cream	Hyperpigmentation, melasma
7	Aramis Fragrance Spray	Fragrance oils (entrapped)	Aramis Inc.	Spray	Controlled fragrance release
8	Microsponge® 520RA	Retinaldehyde	AMCOL (Minerals Technologies)	Powder (cosmetic base)	Anti-aging skincare formulations
9	RetinEZ™ System	Retinol	Minerals Technologies	Cosmetic formulation base	Controlled release anti-aging
10	Microsponge® N	Encapsulated actives	Minerals Technologies	Delivery system	Natural skincare formulations

A list of the medications used in the formulation of the microsponge for oral drug administration

Sr. No.	Active Drug	Formulation Type	Method of Preparation	Polymer Used	Application
1	Domperidone [32]	MSP loaded capsules	Quasi-emulsion solvent diffusion	Eudragit RS-100	Anti-emetic treatment of gastroparesis, emesis, and other stomach disorders
2	Famotidine [33]	Floating MSP	Quasi-emulsion solvent diffusion	Polyvinyl alcohol, Eudragit RS-100	Anti-ulcer
3	Pantoprazole [34] sodium	Tablet	Quasi-emulsion solvent diffusion method	Eudragit RS 100, Polyvinyl alcohol	For the management of Gastroesophageal Reflux Disease (GERD)
4	Luteolin [35]	Gastric floating microsponge	Quasi-emulsion method	–	For targeting *H. pylori* infections
5	Albendazole [36]	–	Oil-in-oil emulsion solvent diffusion method	Eudragit RS100	To target parasitic worms in both humans and animals
6	Lansoprazole [37]	Delayed release MSP	Quasi-emulsion diffusion technique	Eudragit L 100 and Eudragit S 100	Proton pump inhibitor, used as a delivery system for acid labile drug lansoprazole to avoid its degradation in acidic media of the stomach

Recent Advances In Microsponge Drug Delivery System



1. **Polymer Engineering and Tunable Systems [38,39]**

Recent research has focused on the modification of polymeric matrices such as ethyl cellulose and Eudragit to achieve precise control over drug release behavior. Adjustments in pore size, polymer composition, and cross-linking density have enabled improved encapsulation of both hydrophilic and hydrophobic drugs. These

modifications enhance drug stability, reduce degradation, and provide tailored release kinetics, ultimately improving therapeutic efficacy and bioavailability.

2. Expansion Beyond Topical Drug Delivery [30,39]

Although microsponges were initially developed for topical applications, their use has expanded to various pharmaceutical delivery systems. Recent studies have explored microsponge-based oral formulations and modified-release dosage forms to improve drug absorption and pharmacokinetic performance. This advancement has significantly broadened the scope of microsponge technology in pharmaceutical sciences.

3. Hybrid and Composite Drug Delivery Systems [38,40]

The integration of microsponges with other drug delivery carriers has emerged as a promising strategy for enhancing therapeutic outcomes.

3.1 Microsponge–Hydrogel Systems

Microsponge-loaded hydrogels provide prolonged drug retention at the application site and exhibit sustained therapeutic effects, particularly in anti-inflammatory treatments.

3.2 Microsponge–Nanoparticle Systems

The incorporation of nanoparticles into microsponge systems enhances drug penetration, targeting efficiency, and controlled release properties. These hybrid systems offer improved therapeutic performance and extended drug release duration.

4. Stimuli-Responsive (Smart) Microsponges [39]

A significant advancement in microsponge technology is the development of stimuli-responsive systems capable of releasing drugs in response to specific environmental triggers. These include:

- pH-sensitive microsponges for colon-targeted delivery
- Temperature-responsive systems
- Enzyme-triggered delivery systems

Such smart delivery platforms enable site-specific drug release, minimize systemic adverse effects, and improve treatment precision.

5. Applications in Novel Therapeutics [38]

5.1 Herbal and Phytopharmaceutical Delivery

Microsponge systems have demonstrated considerable potential in the delivery of herbal and phytopharmaceutical compounds. They improve the stability of plant-derived active constituents and enhance therapeutic effectiveness. For example, green tea extract-loaded microsponges have shown promising results in the management of skin disorders.

5.2 Periodontal and Dental Drug Delivery

Microsponge-based formulations have been investigated for sustained drug delivery within the oral cavity. Their ability to provide prolonged release makes them suitable for the treatment of chronic oral diseases such as periodontitis, offering a promising alternative to conventional therapies.

6. Improved Topical and Transdermal Delivery Systems

Recent studies have reported significant improvements in topical and transdermal drug

delivery using microsponge technology. These systems provide sustained drug release for extended periods, often exceeding 12 hours, while enhancing skin retention and reducing inflammation. Microsponge-based gels have demonstrated superior performance compared with conventional topical formulations.

7. Advanced Manufacturing Techniques[41]

Modern fabrication approaches have improved the quality and reproducibility of microsponge formulations. Commonly employed techniques include:

- Optimized quasi-emulsion solvent diffusion
- Spray drying
- Solvent evaporation
- Microfluidics-based fabrication

These advanced manufacturing methods enable uniform particle size distribution, enhanced reproducibility, and greater scalability for industrial production.

8. Integration with Emerging Drug Delivery Technologies [42]

Recent research has explored the combination of microsponge technology with advanced drug delivery platforms, including:

- Microneedle-assisted delivery systems
- Microscale drug delivery devices
- Advanced controlled-release technologies

Such integrations enhance drug targeting, improve patient compliance, and increase overall therapeutic efficiency.

FUTURE PROSPECTIVES

MDS has a promising future in the pharmaceutical industry due to its unique properties, which include enhanced product performance and refinement, extended release, less irritation, increased physical, chemical, and thermal stability, and the ability to create innovative product morphologies. MDS is designed to deliver topical antifungal, anti-inflammatory, and anti-dandruff medications. Modifying polymer ratios is essential for the advancement of core/shell microsponge delivery systems for oral peptide administration. In addition, it can be used for tissue engineering and biopharmaceutical delivery of colon-specific pharmaceuticals. Because of the development of novel pharmaceuticals and biopharmaceuticals, drug delivery systems are advancing significantly (peptides, proteins, and DNA-based therapeutics).[43-47] Micro-sized delivery systems are now obsolete, and the search for nanosized carriers is currently intensifying. Micron-sized particles have a much lower ratio of specific surface area to size and a lower capacity to alter active release than nano-sized particles. Although inorganic nanosponges have numerous applications in electronics, more research is required before they can be utilized effectively in medicine. [48-51]

CONCLUSION

Microsponge showing great promise for transforming drug delivery industry. These microscopic polymeric spheres have numerous advantages, including targeted delivery, enhanced stability and controlled release owing to their unique porous structure. Microsponges encapsulate medications within their pores to protect the drugs from degradation, ensuring therapeutic effectiveness. They also have the potential to revolutionise personalised medicine by being able to penetrate deep into tissues while

selectively delivering drugs at a precise site. Hence, it is obvious that efficient designs in drug delivery systems based on microsponges will be pivotal to improving the results for patients and leading science into a better future.

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