INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

Review Article

Mucoadhesive Nasal Microspheres: A Novel Approach for Enhanced Drug Delivery

Ganesh Patel*, Sandip Tadavi, Dr. Sunil Pawar

Department of Pharmaceutics, P.S.G.V.P. Mandal's College of pharmacy, Shahada-425409, Dist.-Nandurbar, Maharashtra, India.

ARTICLE INFO

Published: 27 Mar. 2025
Keywords:
Nasal Microspheres, Mucoadhesion, Drug Delivery, Bioavailability, Controlled Release, Polymeric Microspheres.
DOI:
10.5281/zenodo.15093587

ABSTRACT

Mucoadhesive nasal microspheres represent a promising drug delivery system designed to enhance the bioavailability and therapeutic efficacy of drugs administered via the nasal route. These microspheres are typically composed of biocompatible and biodegradable polymers, which adhere to the mucosal lining of the nasal cavity, allowing for controlled drug release and prolonged retention time. This innovative approach not only improves the drug's absorption but also minimizes side effects, as it bypasses the first-pass metabolism. The mucoadhesive properties of the microspheres facilitate sustained drug release, making them particularly suitable for both local and systemic delivery of therapeutic agents. In addition to their ability to deliver a wide range of drug types, including proteins, peptides, and small molecules, the microspheres offer advantages such as ease of administration, non-invasive nature, and patient compliance. This paper discusses the formulation, characterization, and potential applications of mucoadhesive nasal microspheres in various therapeutic fields, including pain management, vaccines, and the treatment of chronic diseases. The future of mucoadhesive nasal microspheres lies in their ability to offer a targeted, efficient, and patient-friendly alternative to traditional drug delivery systems.

INTRODUCTION

The history of nasal drug delivery dates back to earlier topical applications of drugs intended for local effects. Nasal therapy also called "Navya karma has been recognized form of treatment in the Ayurvedic system of Indian medicines.[1] Nasal route is easily accessible, convenient, and reliable with a porous endothelial membrane and a highly vascularised epithelium that provides a rapid absorption of compounds into the systemic circulation, avoiding the hepatic first pass

***Corresponding Author:** Ganesh Patel
Address: Department of Pharmaceutics, P.S.G.V.P. Mandal's College of pharmacy, Shahada-425409, Dist.-Nandurbar, Maharashtra, India.
Email ✉: ganeshspatel106@gmail.com
Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

elimination. In addition, intrananal drug delivery enables dose reduction, rapid attainment of therapeutic blood levels, quicker onset of pharmacological activity, and fewer side effects.[2,3] The nasal route is conventionally used for drug delivery for treatment of local diseases such as nasal allergy, nasal congestion and nasal infections[4,5]. But in the recent years, this route has received special attention as a convenient and reliable method for the systemic delivery of drugs, especially those that are ineffective by oral route due to their metabolism in the gastrointestinal tract or by first-pass effect and must be administered by injection.[6] Among other promising non-parenteral routes, the nasal route of administration may perfectly satisfy the pre-requisites for non-oral, non-parenteral systemic medication purpose[7] Microspheres are solid spherical particles ranging in size from 1-1000µm. They are spherical free flowing particles consisting of proteins or synthetic polymers. The microspheres are free flowing powders consisting of proteins or synthetic polymers, which are biodegradable in nature. There are two types of microspheres; microcapsules and micromatrices, which are described as, Microcapsules are those in which entrapped substance is distinctly surrounded by distinct capsule wall and micromatrices in which entrapped substance is dispersing throughout the microspheres matrix. Solid biodegradable microspheres incorporating a drug dispersed or dissolved through particle matrix have the potential for the controlled release of drug. They are made up of polymeric, waxy, or other protective materials, that is, biodegradable synthetic polymers and modified natural products.[8]

MATERIAL AND METHODS

MATERIAL:

1. Synthetic Polymers

Poly alkyl cyano acrylates is a potential drug carrier for parenteral as well as other ophthalmic, oral preparations. Poly lactic acid is a suitable carrier for sustained release of narcotic antagonist, anti-cancer agents such as cisplatin, cyclophosphamide, and doxorubicin. Sustained release preparations for anti-malarial drug as well as for many other drugs have been formulated by using of co-polymer of poly lactic acid and poly glycolic acid. Poly anhydride microspheres (40µm) have been investigated to extend the precorneal residence time for ocular delivery. Poly adipic anhydride is used to encapsulate timolol maleate for ocular delivery. Poly acrolein microspheres are functional type of microspheres. They do not require any activation step since the surfacial free CHO groups over the poly acrolein can react with NH2 group of protein to form Schiff's base[24] Synthetic polymers are divided into two types.

a. non-biodegradable polymers: e.g. Poly methyl methacrylate (PMMA) Acrolein Glycidyl methacrylate Epoxy polymers

b. Biodegradable polymers: e.g. Lactides, Glycolides & their co polymers, Poly alkyl cyano acrylates, Poly anhydrides.[24]

2. Natural polymers

Albumin is a widely distributed natural protein .It is considered as a potential carrier of drug or protiens (for either their site specific localization or their local application into anatomical discrete sites). It is being widely used for the targeted drug for the targeted drug delivery to the tumour cells. Gelatin microspheres can be used as efficient

carrier system capable of delivering the drug or biological response modifiers such as interferon to phagocytes[24,25] Starch belongs to carbohydrate class. It consists of principle glucopyranose unit, which on hydrolysis yields D-glucose. It being a poly saccharide consists of a large number of free OH groups. By means of these free OH groups a large number of active ingredients can be incorporated within as well as active on surface of microspheres. Natural polymers are divided into different sources like proteins, carbohydrates and chemically modified Carbohydrates, Proteins: Albumin6, Gelatin7, and Collagen. Carbohydrates: Agarose, Carrageenan, Chitosan, Starch. Chemically modified carbohydrates: Poly dextran, Poly Starch. In case of non-biodegradable drug carriers, when administered parenterally, the carrier remaining in the body after the drug is completely released poses possibility of carrier toxicity over a long period of time[25]

Methods:

The microspheres can be prepared by using any of the several techniques given below but choice of the technique mainly depends on the nature of the polymer used, the drug, the intended use and the duration of therapy

1) Single Emulsion Technique [8]

The micro particulate carriers of natural polymers i.e., those of proteins and carbohydrates are prepared by single emulsion technique. The natural polymers are dissolved or dispersed in aqueous medium followed by dispersion in non-aqueous medium e.g., oil. In the second step of preparation cross-linking of the dispersed globule is carried out. The cross linking can be achieved either by means of heat or by using the chemical crosslinkers. The chemical cross linking agent used include gluteraldehyde, formaldehyde, terephthaloyl chloride, diacid chloride, etc. Croslinking by heat is carried out by adding the dispersion, to previously heated oil. Heat denaturation is however, not suitable for the thermolabile drugs while the chemical cross-linking suffers disadvantage of excessive exposure of active ingredient to chemicals if added at the time of preparation.

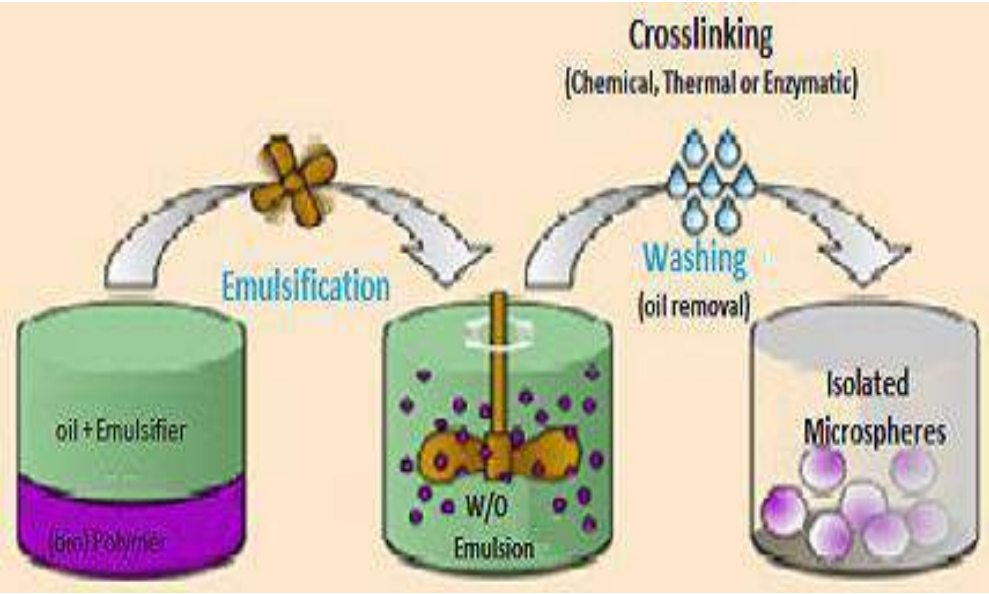

Fig.1. Microspheres By Single Emulsion Technique

2) Double Emulsion Technique [9,10]

Involves the formation of the multiple emulsions or the double emulsion of type w/o/w and is best suited to the water-soluble drugs, peptides, proteins and the vaccines. This method can be used with both the natural as well as the synthetic polymers. The aqueous protein solution is dispersed in a lipophilic organic continuous phase. This protein solution may contain the active constituents. The continuous phase is generally consisted of the polymer solution that eventually encapsulates of the protein contained in dispersed aqueous phase. The primary emulsion is then subjected to the homogenization or the sonication before addition to the aqueous solution of the polyvinyl alcohol (PVA). This results in the formation of the double emulsion. The emulsion is then subjected to the solvent removal either by solvent evaporation or by solvent extraction process. The solvent evaporation is carried out by maintaining emulsion at reduced pressure or by stirring the emulsion so that the organic phase evaporates out. In the latter case, the emulsion is added to the large quantity of water (with or without surfactant) into which organic phase diffuses out. The solid microspheres are subsequently obtained by filtration and washing. A number of hydrophilic drugs like luteinizing hormone releasing hormone (LH-RH) agonist; vaccines, proteins/peptides and conventional molecule are successfully incorporated in to the microspheres using the method of double emulsion solvent evaporation/extraction.

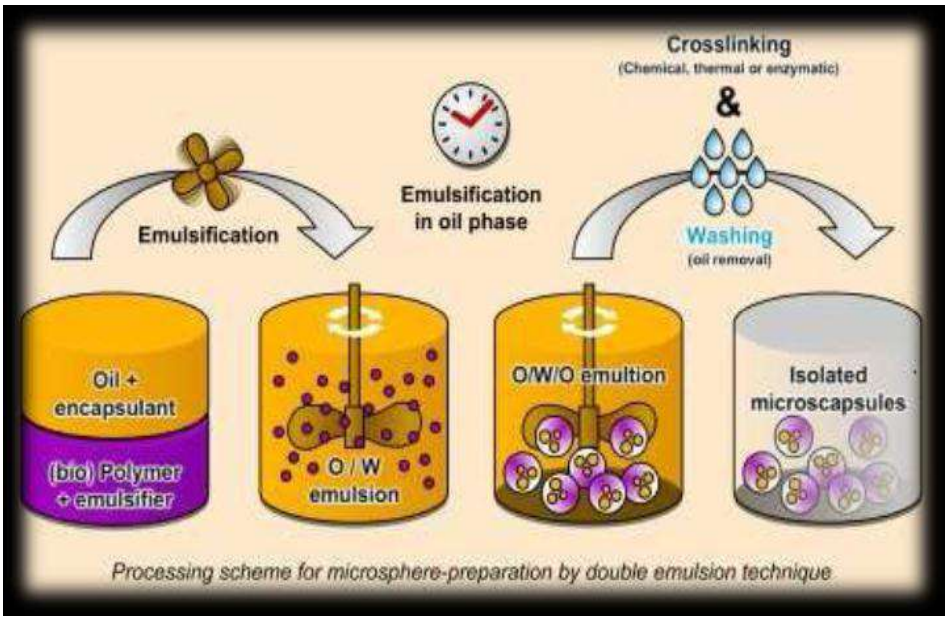

Fig.2. Microspheres by Double emulsion technique

3) Spray Drying and Congealing Technique [9,10]

Spray drying and spray congealing methods are based on the drying of the mist of the polymer and drug in the air. Depending upon the removal of the solvent or the cooling of the solution, the two processes are named spray drying and spray congealing respectively. The polymer is first dissolved in a suitable volatile organic solvent such as dichloromethane, acetone, etc. The drug in the solid form is then dispersed in the polymer solution under highspeed homogenization. This dispersion is then atomized in a stream of hot air. The atomization lead to the formation of small

droplets or the fine mist from which the solvent evaporates leading to the formation of microspheres in a size range 1-100µm. Microparticles are separated from the hot air by means of the cyclone separator while the traces of solvent are removed by vacuum drying.

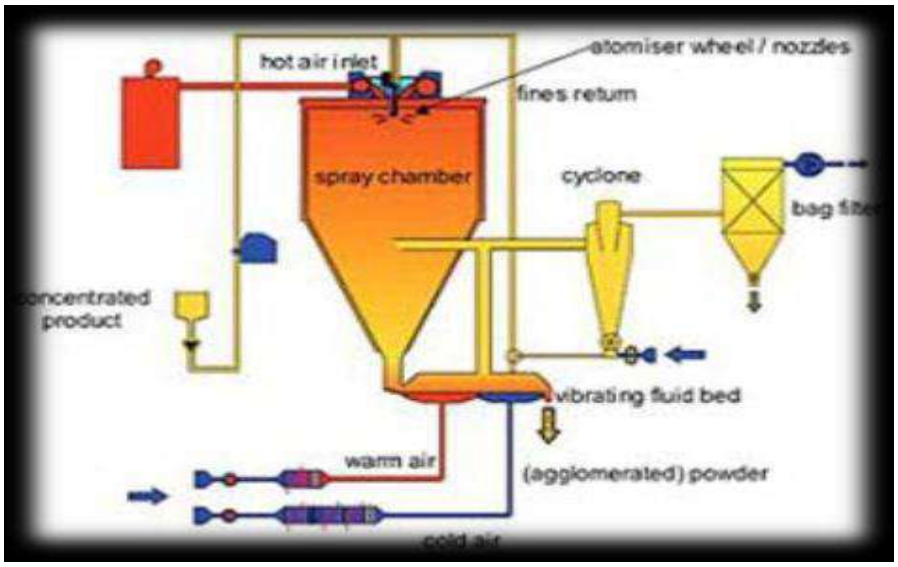

Fig.3. Microspheres by Spray Drying technique

4) Polymarization Technique

- **Interfacial Polymerization** [11,12]

It involves the reaction of various monomers at the interface between the two immiscible liquid phases to form a film of polymer that essentially envelops the dispersed phase. In this technique two reacting monomers are employed; one is dissolve in continuous phase while other is disperse in continuous phase (aqueous in nature) throughout which the second monomer is emulsified. Two conditions arise because of solubility of formed polymer in the emulsion droplet. That is formation is monolithic type of carrier if the polymer is soluble in droplet. Capsular type formed if the polymer is insoluble in droplet.

- **Normal Polymerization** [13]

Proceeds using techniques like bulk, suspension precipitation, emulsion & micellar polymerization processes. In bulk polymerization, a monomer along with initiator is heated to initiate polymerization. Initiator is added to accelerate the rate of reaction. Drug is added during process of polymerization. The polymer so obtained is fragmented to microspheres.

- **Suspension Polymerization**

Suspension polymerization is also called as bead/pearl polymerization. Carried out by heating the monomer or mixture of monomers with active principles (drug) as droplets dispersion in a continuous phase. The droplets may also contain an initiator & other additives. The emulsion polymerization differs from the suspension polymerization as due to presence of initiator in the aqueous phase, which later on diffuses to the surface of the micelles or the emulsion globules. The suspension & emulsion polymerization can be carried out at lower temperature since continuous external phase is normally water through which heat can easily dissipate. The processes also lead

to the formation of higher molecular weight polymer at relatively faster rate.

5) Solvent Extraction [14]

Solvent evaporation has been extensively used for the preparation of PLA and PLGA microspheres which contain various drugs. Several variables are identified that can significantly affect microspheric characteristics, such as solubility of drug, internal morphology, type of solvent, diffusion rate, temperature, polymer composition, viscosity, and drug loading. The efficacy of this method relies on the effective entrapment of the active substance into the particles, and therefore this procedure is particularly efficient with drugs that are either insoluble or partially soluble in the liquid medium.

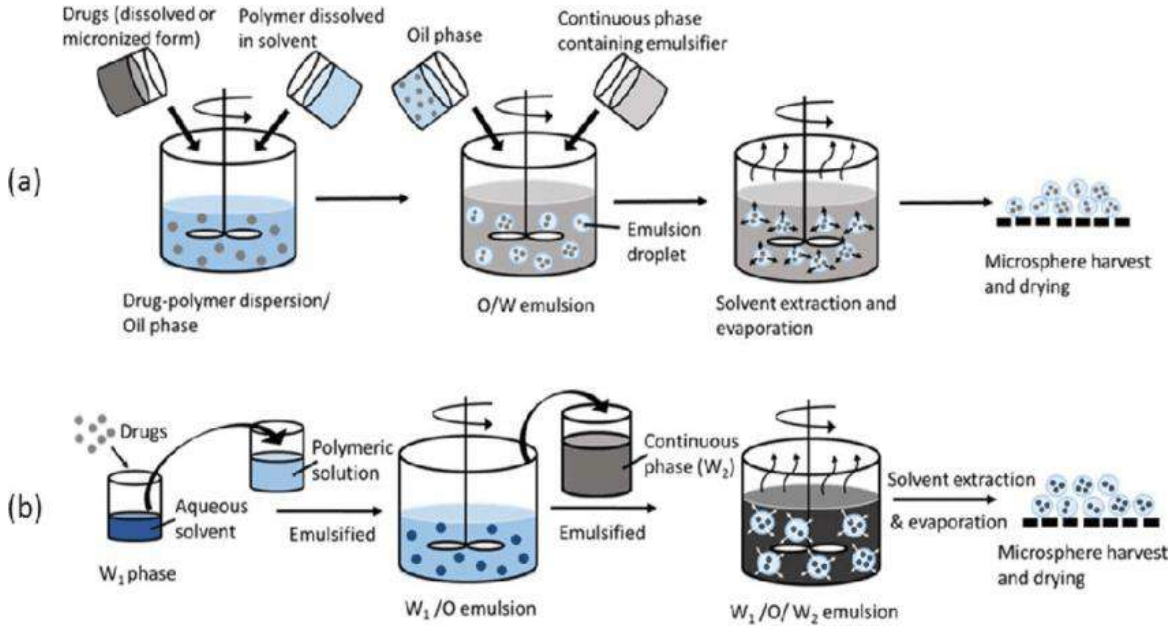

Fig.4. Microspheres By Solvent Extraction Technique

6) Quasi Emulsion Solvent Diffusion [15]

Quasi-emulsion solvent diffusion method is used for the manufacturing of the controlled release microspheres of drugs with acrylic polymers. Microsponges can be manufactured by this method by using external phase which contains distilled water and polyvinyl alcohol. Internal phase consists of the drug, ethanol and polymers. Firstly, the internal phase is heated at 60ºC and added to the external phase in the room temperature. The mixture is stirred continuously for 2 hours. Then the mixture can be filtered for separation of the microsponges.

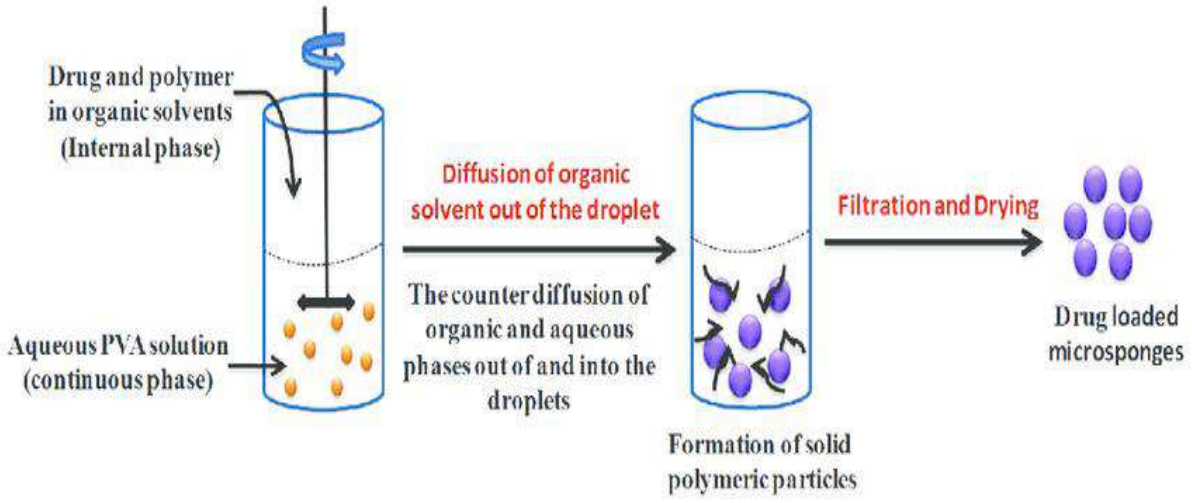

Fig.5. Microspheres by Quasi-emulsion technique

Types Of Microspheres

Microspheres are classified into different types. They are of following

1. Bioadhesive microspheres
2. Magnetic microspheres
3. Floating microspheres
4. Radioactive microspheres

1. Bioadhesive microspheres [16]

Sticking of drug to the membrane by using the watersoluble property of the water-soluble polymers is called adhesion. Sticking or adhesion of drug delivery system to the mucosal membrane such as buccal, nasal, ocular, rectal etc can be termed as bioadhesion. This type of microsphere provides prolonged residence time at the target site and provide better therapeutic action.

2. Magnetic microspheres [17]

This type of delivery system localizes drug to the target site. In this type of delivery system, a drug or therapeutic radioisotope bound to a magnetic component is injected in the systemic circulation, which is then stopped with powerful magnetic field in the disease/target site. Magnetic microspheres are molecular particles which are small enough to move across capillaries without creating an esophageal occlusion

3. Floating microspheres [18]

In floating type, the bulk density is less than the gastric fluid and so remains buoyant in stomach without affecting gastric emptying rate. The drug is released slowly at the desired rate, and the system is found to be floating on gastric contents and decrease gastric residence and increases fluctuation in plasma concentration. Moreover, it also reduces chances of dose dumping. It produces prolonged effect and so reduces dosing frequencies.

4. Radioactive microspheres [19,20]

Radio embolization therapy microspheres sized 10-30nm are of larger than the diameter of the capillary bed when they come across. They are injected in the arteries that lead them to tumour of interest so all these conditions radioactive microspheres deliver high radiation dose to the targeted areas without damaging the normal

surrounding tissues. Here radioactivity is not released from microsphere but acts within a radioisotope in typical distance. The different types of radioactive microspheres are α emitters, β emitters and ϒ emitters.

Advantages of Microspheres: [21,22]

- Decreased size of microsphere contributes increased surface area thereby increases the potency of the poorly soluble material
- Dose frequency and adverse effects can be reduced.
- Increased patient compliance.
- Drug packaged with polymer prevent drug from enzymatic cleavage therefore the drug can be protected from various enzymes.
- Enhances bioavailability.
- Gastric irritation can be reduced.
- Biological half-life can be enhanced.
- First pass metabolism can be reduced.
- Unpleasant odour and taste of the drug can be masked.

Disadvantages of Microspheres:[23]

- Reproducibility is less.
- The cost of materials and processing is high compared to conventional preparations.
- Change in process variables such as change in temperature, pH, solvent addition and evaporation/agitation may influence the stability of core particles.
- The fate of polymer matrix and additives.

Characterisation And Evaluation Of Microsphere:

- **Particle size determination**

Particle size was determined by optical microscopy with the help of calibrated eyepiece micrometer. The size of around 100 microspheres was measured and their average particle size determined. The average particle size was determined by using Edmundson's equation.

D mean = Σnd/Σn

Where, n = Number of microspheres checked; d = Mean size.

Median size of the microspheres formulations ranged from 15 to 40 um were considered to be suitable for nasal administration.

- **Drug entrapment efficiency**

Microspheres containing of drug (5mg) were crushed and then these microspheres dissolved in distilled water with the help of ultrasonic stirrer for 3 hr, and then filtered and assayed by uv-visible spectroscopy and then entrapment efficiency is calculated. Entrapment efficiency is equal to ratio of actual drug content to theoretical drug content.

% Entrapment = Actual content/Theoretical content x 100

Percentage yield: The yield was calculated for each batch. The percentage yield of microspheres was calculated as follows.

{% Yield= Weight of Microspheres /Theoretical weight of drug and polymer x100}

- **Equilibrium swelling degree**

The equilibrium swelling degree (ESD) of microspheres was determined by swelling 5gms of

dried microspheres in 5 ml of phosphate buffer pH 6.8 overnight in a measuring cylinder. The swelling index of the microsphere was calculated by using the formula.

Swelling index= Initial weight – Final weight/ Initial weight × 100

- **Density determination**

The density of the microspheres can be measured by using a multi volume pychnometer. Accurately weighed sample in a cup is placed into the multi volume pychnometer.

Helium is introduced at a constant pressure in the chamber and allowed to expand. This expansion results in a decrease in pressure within the chamber. Two consecutive readings of reduction in pressure at different initial pressure are noted. From two pressure readings the density of the microsphere carrier is determined[26,27,28]

- **Surface Topography**

The samples for the scanning electron microscope (SEM) analysis were prepared by sprinkling the microspheres on one side of an adhesive stub. Then the microspheres were coated with gold before microscopy[28]

- **UV-FTTR (Fourier transform infrared)**

The drug polymer interaction and degradation of drug while processing for microencapsulation can be determined by FTIR

- **Ex vivo permeation studies**

Ex-vivo drug permeation study was performed using a glass fabricated nasal diffusion cell. The water jacketed recipient chamber has a total capacity of 60 ml and flanged top of measured by a u-tube viscometer (viscometer constant at 400c is 0.0038 Mm2/s /s) at 25 ± 0.1 0c in a thermostatic bath. The polymer solutions are allowed to stand for 24 h prior to measurement to ensure complete polymer dissolution.[29,30]

Future Opportunities:

1. Drug Delivery Systems

- **Targeted Drug Delivery**: Microspheres are already being used to deliver drugs directly to specific parts of the body, and future innovations will likely improve the precision of these systems. Researchers are exploring how to modify the surface of microspheres with specific targeting ligands that can recognize and bind to particular cell receptors, allowing for more effective and less toxic treatments.

- **Controlled and Sustained Release**: Microspheres could be designed to release drugs over extended periods, reducing the frequency of administration. This is especially useful in treating chronic conditions and improving patient compliance.

- **Gene Delivery**: Advances in microsphere technology may enable the delivery of genetic materials like RNA or DNA to specific cells, contributing to gene therapies for various genetic disorders.

2. Diagnostics

- **Imaging**: In medical diagnostics, microspheres could be used as contrast agents in imaging techniques like MRI or ultrasound. Future developments might involve creating microspheres with enhanced properties that can provide clearer, more detailed images or better identify diseases at an earlier stage.

- **Biosensors**: Microspheres can be functionalized with antibodies or other biomolecules, enabling them to bind to specific targets in biological samples. This technology could lead to more sensitive and rapid diagnostic tests for conditions like cancer, infections, or autoimmune diseases.

3. Biotechnology and Cell Culture

- **Tissue Engineering**: Microspheres made from biodegradable materials may play a role in scaffold-based tissue engineering. By creating microenvironments that support cell growth and differentiation, microspheres could help in regenerating damaged tissues and organs.

- **Cell Encapsulation**: Microspheres could encapsulate cells, such as insulin-producing cells for diabetes treatment. Future advances might improve the efficiency and survival of encapsulated cells, making them viable for a broader range of therapeutic applications.

4. Materials Science

- **Smart Materials**: Microspheres could be engineered into "smart" materials that respond to external stimuli, such as changes in temperature, pH, or light. These could be used in various fields, including smart coatings, sensors, and actuators.

- **Nanotechnology Integration**: The integration of microspheres with nanotechnology might lead to even more powerful applications. For example, microspheres could serve as carriers for nanoparticles, enabling the development of advanced composite materials with unique properties (e.g., increased strength, conductivity, or thermal resistance).

5. Cosmetics and Personal Care

- **Cosmetic Formulations**: Microspheres are already used in personal care products for their ability to improve texture, provide controlled release of active ingredients, or serve as exfoliating agents. In the future, microspheres might be designed to provide even more targeted and controlled release of substances like vitamins, anti-aging compounds, and moisturizers.

- **Skin Care**: Microspheres could also play a role in protecting and enhancing the skin barrier by encapsulating active ingredients and releasing them in a controlled manner, thus improving efficacy while minimizing irritation.

6. Environmental and Industrial Applications

- **Water Treatment**: Microspheres could be used to remove pollutants from water or as part of filtration systems to capture contaminants. As environmental concerns increase, microspheres could be modified to target specific pollutants or even used in cleanup efforts for oil spills or hazardous waste.

- **Catalysis**: In industrial settings, microspheres may serve as catalysts for chemical reactions. These catalysts can increase reaction rates and efficiency, particularly in processes like petroleum refining or the production of fine chemicals.

7. Advanced Manufacturing

- **3D Printing**: Microspheres could be used in advanced 3D printing techniques to produce intricate structures with unique properties. The ability to control the size and composition of microspheres could result in more precise and customizable materials for various applications.

8. Sustainability and Biodegradability

- **Eco-friendly Microspheres**: As sustainability becomes a priority, there is growing interest in creating biodegradable microspheres made from natural or sustainable materials. These could replace petroleum-based microspheres, particularly in cosmetics, packaging, and industrial applications, to reduce environmental impact.

- **Waste Reduction**: Microspheres made from recycled materials or bio-based substances might contribute to a circular economy and the reduction of plastic waste.

CONCLUSION:

In conclusion, microspheres represent a versatile and rapidly advancing technology with significant potential across various industries, including medicine, biotechnology, materials science, cosmetics, and environmental applications. Their ability to encapsulate and deliver active agents in a controlled and targeted manner holds particular promise for drug delivery systems, diagnostics, and tissue engineering. As research continues, innovations in microsphere materials and functionalities are expected to lead to more efficient, sustainable, and personalized solutions, with applications ranging from targeted therapies and gene delivery to advanced materials and eco-friendly products. The future of microspheres is poised to transform numerous fields, improving the quality of life, enhancing industrial processes, and contributing to environmental sustainability. However, as these technologies develop, ensuring their safety, efficacy, and environmental impact will be critical in maximizing their benefits and minimizing potential risks. With ongoing advancements, microspheres will continue to play a key role in shaping the future of science, healthcare, and technology.

REFERENCES

1. Pagar Swati Appasaheb, Shinkar Dattatraya Manohar, Saudagar Ravindra Bhanudas. Journal of Advanced Pharmacy Education and Research, 2013; 3(4): 333-346
2. Ugwoke MI, Verbek N, Kinget R. The biopharmaceutical aspects of nasal mucoadhesion drug delivery. Journal of Pharmcy and Pharmacology, 2001; 59: 3–22.
3. Arora P, Sharma, Gary S. Permeability issues in nasal drug delivery. Drug Discovery Today, 2002; 7: 967–975.
4. Illum L.: Nasal drug delivery-possibilities, problems and solutions. J Controlled Release. 2003; 87: 187-198.
5. Mainardes R.M., Cocenza Urban M.C., Cinto P.O., Chaud M.V., Evangelista R.C.: Liposomes and micro /nanoparticles as colloidal carriers for nasal drug delivery. Curr Drug Delivery. 2006; 3: 275-285.
6. Hussain A. A.: Intranasal drug delivery. Adv Drug Deliv Rev.1998; 29: 39-49.
7. Krishnamoorthy R., Mitra A.K.: Prodrugs for nasal drug delivery. Adv Drug Deliv Rev. 1998; 29: 135-146.
8. S.P.Vyas and R.K.khar “Targeted and Controlled Drug Delivery: Novel Carrier System 1st edition. CBS publication and distributors, New Delhi 2002, page no. 81-121.
9. J.H Ratcliff, I.M Hunnyball, A. Smith and C.G Wilson, J.Pharmacol. 1984,431-436.
10. S Fujimoto, M.Miyazaki et.al. Biodegradable motomycin C microspheres. Given intra-arterially for hepatic cancer, 1985, page no.2404-2410.
11. Jain NK. Advances in controlled & Novel drug delivery, 03 Edition, 71. CBS publication. delhi, 2004.
12. Jayaprakash S, Halith S M, Mohamed Firthouse P U, Kulaturanpillai K, Abhijith, Nagarajan M. Preparation and evaluation of

biodegradable microspheres of methotrexate. Asian J Pharm, 2009; 3: 26-9.

13. Anil Kumar, Sourav Mahajan and Neeraj Bhandari, Microspheres: A Review World Journal Of Pharmacy and Pharmaceutical Sciences, Volume 6, Issue 4, 724-740.
14. Yadav R, Bhowmick M, Rathi V, Rathi J, Design and characterization of floating microspheres for rheumatoid arthritis, Journal of Drug Delivery and Therapeutics 2019; 9(2-s):76-81.
15. Abbaraju Krishna shailaja, et. al., Biomedical applications of microspheres, Journal of Modern Drug Discovery and Drug Delivery Research, 2015;4(2):1-5.
16. Chaware P, Sharma S, Bhandari A, Garud A, Garud N. Bioadhesive Microspheres: A Review on Preparation and In-Vitro Characterization. World Journal of Pharmaceutical Research. 2014;4(2):423-36.
17. Farah Hamad Farah, et. al., Magnetic Microspheres: A Novel Drug Delivery System, Analytical and Pharmaceutical Research. 2016;3(5):1-10. DOI: 10.20959/wjpps20179-10054.
18. Jagtap Yogesh Mukund, et. al., Floating microspheres: a review, Brazilian Journal of Pharmaceutical Sciences, 2012;48(1):17-30.
19. Urs Hafeli, et. al., Review: Radioactive Microspheres for Medical Applications, Cleveland Clinic Foundation, Radiation Oncology Department T28, page 1-29.
20. Lachman LA, Liberman HA, Kanig JL. The Theory and Practice of Industrial Pharmacy. Varghese Publishng House, Mumbai, India: 1991, 3rd edition; P-414-415.
21. Kadam N. R. and Suvarna V, Microspheres: A Brief Review, Asian Journal of Biomedical and Pharmaceutical Sciences, 2015;3(4):13-15.
22. Virmani Tarun and GuptaJyoti, Pharmaceutical Application of Microspheres: An Approach for the Treatment of Various Diseases; International Journal of Pharmaceutical Sciences and Research, 2017; 8(1): 3257- 3259. DOI: 10.13040/IJPSR.0975-8232
23. Virmani Tarun and Gupta Jyoti, Pharmaceutical Application of Microspheres: An Approach for the Treatment of Various Diseases; International Journal of Pharmaceutical Sciences and Research, 2017; 8(1): 3257- 3259. DOI: 10.13040/IJPSR.0975-8232
24. M.Alagusundaram et.al. Nasal drug delivery system - an overview. M. Alagusundara et.al. | Int. J. Res. Pharm. Sci. Vol-1, Issue-4, 454-465, 2010©Pharmascope.
25. . Alpesh M, Snjezana S, Lisbeth I. Nanoparticles for direct nose-to-brain delivery of drugs. 2009; 379: 146-57
26. Mitra S, Gaur U, Ghosh PC, Tumor targeted delivery of encapsulated dextrandoxorubicin conjugate using Chitosan nanoparticles as carrier. J Control Release. 2001; 74(1–3): 317–323.
27. Capan Y, Jiang G, Giovagnali S, Na KH, Deluca PP. Preparation and characterization of poly (D,L-lactide-co-glycolide) microspheres for controlled release of human growth harmon. AAPS Pharm Sci Tech. 2003; 4: 1–10.
28. B. Lindberg, K. Lote, H. Teder, Biodegradable starch microspheres-A new medical tool, in: S.S. Davis, L.
29. Illum, J.G. McVie,E. Tomlinson (Eds.), Microspheres and Drug Therapy. Pharmaceutical, Immunological and Medical Aspects, Elsevier, Amsterdam, 1984; 153-188.
30. U. Conte, P. Giunchedi, L. Maggi, M.L. Torre, Spray dried albumin microspheres containing nicardipine, Eur. J. Pharm Biopharm. 1994; 40: 203-208.

31. N.F. Farraj, B.R. Johansen, S.S. Davis, L. Illum, Nasal administration of insulin using bioadhesive microspheres as a drug delivery system, J Control Release,1990; 80: 161- 169.

HOW TO CITE: Ganesh Patel*, Sandip Tadavi, Dr. Sunil Pawar, Gopal Thakur, Arshiya Sharma, Aparna Thakur, Mucoadhesive Nasal Microspheres: A Novel Approach for Enhanced Drug Delivery, Int. J. of Pharm. Sci., 2025, Vol 3, Issue 3, 2615-2627 https://doi.org/10.5281/zenodo.15093587