RESEARCH ARTICLE

Design, Optimization and Performance Assessment of Memantine Buccal Films for Targeted Drug Delivery

Venkata Durga Seshu Priya P[1], Ruby S[2*], Kumar M[2]

[1]Department of Pharmaceutics, Vinayaka Mission's College of Pharmacy, VMRF(DU), Salem, Tamil Nadu, India.
[2]Department of Pharmaceutical Chemistry, Vinayaka Mission's College of Pharmacy, VMRF(DU), Salem, Tamil Nadu, India.

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ABSTRACT

Memantine is primarily prescribed for treating moderate to severe Alzheimer's disease by modulating glutamate, a key neurotransmitter involved in cognitive functions like memory and learning. By blocking excessive glutamate activity at NMDA receptors, memantine helps improve cognitive function and slow symptom progression in Alzheimer's patients. In this study, solvent evaporation was used in the formulation of memantine in order to increase its bioavailability and sustain its release. Chitosan, HPMC, a mucoadhesive polymer, carbopol, a sensitive to pH polymer and propyle glycol, a permeation enhancer, were all incorporated in the formulation. All formulations underwent evaluation for moisture content, folding endurance, swelling index, mucoadhesive strength and drug content. Drug release profiles were assessed through *in-vitro* diffusion studies. Results indicated that increasing concentrations of polymers led to higher mucoadhesive strength, consequently enhancing Memantine release from the system. The optimal formulation(F9), with carefully balanced polymer concentrations, demonstrated more resident time, sustained drug release and improved bioavailability.

Keywords: Sustained Release, Mucoadhesive strength, Buccal mucosa, Permeation enhancer, Gelling agent.

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INTRODUCTION

The concept of a buccal drug delivery system revolves around the administration of medications through the buccal mucosa, which is the inner lining of the cheeks. This method leverages the unique properties of the buccal mucosa to provide an efficient and effective way to deliver drugs.[1] This transformation enables sustained drug release, improved bioavailability and enhanced therapeutic effectiveness.[2] These formulations are particularly advantageous for delivering drugs to mucosal surfaces. They adhere to these surfaces upon application, prolonging the residence time of the drug and facilitating targeted delivery. Buccal films are used in a variety of applications, including controlled medication release, tissue manipulation and regeneration therapy.[3]

Delivering drugs through buccal drug delivery offers a number of advantages, such as a quick start to action, avoiding first-pass metabolism and improving patient adherence. Drugs administered through the buccal route are absorbed directly through the highly vascularized mucosa, facilitating rapid entry into the bloodstream.[4] This route is particularly beneficial for drugs with poor oral bioavailability or those susceptible to degradation in the digestive system. Common applications include decongestants, hormones, vaccines and treatments for neurological conditions.[5] Moreover, buccal delivery is being explored for its potential to target the central nervous system via direct pathways from the buccal cavity. This offers promising new therapeutic avenues for diseases like Alzheimer's, migraine and epilepsy. Overall, buccal drug delivery represents a promising approach in drug administration, combining ease of use with potential improvements in therapeutic outcomes.[6]

MATERIALS AND METHODS

Yarrow Chemicals provided a gift sample of memantine, while S.D. Fine Chemicals sent HPMC, Chitosan, and Carbapol from Mumbai, India.

Calibration Curve of Memantine

Begin by precisely weighing 10 mg of memantine and dissolving it in methanol. After dispersing the memantine, transfer it to a 10 mL volumetric bottle and top it off with methanol.[7] Pipette the generated stock solution into separate 100 mL volumetric flasks at volumes of 0.5, 1, 1.5, 2, and 2.5 mL. To obtain concentrations of memantine within a range of 10 to 25 µg/mL, adjust the contents in each flask.[8] The absorbance of each diluted solution should then be measured using a UV-visible spectrophotometer at 254 nm.

*Author for Correspondence: ruby.s5902@gmail.com

Table: 1 Formulation of memantine buccal film

Formulation Codes	*Drug (mg)*	*Polymers (mg)*				*Solvents (mL)*		
		HPMC	*Chitosan*	*Carbopol*	*P.V.P*	*Ethanol (70%)*	*Distil. water*	*PG (30% w/w)*
F1	10	2.5	-	-	1	5.5	4.0	1
F2	10	-	2.0	-	1	5.5	4.0	1
F3	10	-	-	2.5	1	5.5	4.0	1
F4	10	1.0	0.5	0.5	1	5.5	4.0	1
F5	10	0.5	1.0	0.5	1	5.5	4.0	1
F6	10	0.5	0.5	1.0	1	5.5	4.0	1
F7	10	1.5	0.25	0.25	1	5.5	4.0	1
F8	10	0.25	1.5	0.25	1	5.5	4.0	1
F9	10	2	0.5	-	1	5.5	4.0	1
F10	10	0.25	0.25	1.5	1	5.5	4.0	1
F11	10	-	2.0	0.5	1	5.5	4.0	1
F12	10	0.5	2.0	-	1	5.5	4.0	1

Fabrication of Buccal Film

Seventy percent ethanol was used to dissolve the measured amounts of polymers. The carbopol polymeric solution was neutralized using triethanolamine. Following a 30% w/w propylene glycol levigation, the medication was added to the polymeric solution in exact doses of 10 mg. The solution was blended occasionally to get a glue-like consistency. The drug and polymer blend mixture was poured in petridish and kept aside for one week for the dissipation of dissolvable present in the blend. At long last, after clear examination, the dried films were taken and inspected for any air pockets and particular breadth films created utilizing an extraordinarily manufactured round stainless steel cutter.[9-16] The compositions of the films were given in Table 1.

Evaluation Parameters

Weight variation

For the weight variation test, three 2 × 1 cm^2 disks were cut and weighed on an electronic balance. The purpose of the test was to measure weight homogeneity and, consequently, batch-to-batch fluctuation.

Thickness

Digital Vernier calipers with a least count of 0.001 mm were used to measure the thickness of the films. Five distinct locations were used to measure the thickness uniformity, and the average of those measurements was calculated using the standard deviation.

Folding endurance

For the prepared films, the folding endurance was measured by hand. A 4 × 3 cm strip of film was cut uniformly, then folded in the same spot over and over until it broke. The precise figure of folding endurance was determined by counting the number of times the film could be folded in the same way without breaking.

Surface pH

The modified method initially revealed that the pH of the buccal films did not contain the support layer. In petri dish contain 2% agar in warmed phosphate buffer (pH 6.7) solution and keep the buccal film at room temperature. The glass anode was in contact with the surface of the film for up to 1 minute to determine the surface pH. The technique was repeated thrice and the normal was noted.

Mucoadhesive force

Using a specially designed biological adhesion testing apparatus that served as an *in-vitro* mucoadhesion test, the force needed to remove each formulation from goat nasal mucous membranes was used to calculate the adhesive strength of each formulation.[17]

Adhesion force

Goat buccal mucosa that was purchased commercially was collected and placed in a sterile container with a sterilized buffer solution (pH 6.7). After being taken out of refrigeration, the mucosa was given time to acclimate to the laboratory setting. After that, connective and adipose tissue were carefully removed and the area was cleaned with simulated buccal solution.[18]

Next, the membrane was positioned and fastened to the lower Teflon block (B). This assembly was kept at 35 ± 2°C and submerged in a beaker filled with a simulated buccal solution at pH 6.7. The bottom of the upper Teflon block was covered with film from each batch. The mucosal tissue was fixed on the lower cylinder (B) of the beaker and it was placed on a balance so that it was precisely below the upper cylinder. To enable the film to bind with mucin, a 10 g weight was put on the inflated cap for 10 minutes after a drop of simulated buccal solution was applied to the exposed portion of the film. After removing the first weight, more weights were progressively added to the right-side pan until the film was completely separated from the mucosal layer. W1, which stands for the force needed for

detachment in grams, was recorded as the weight needed for total detachment (e.g., W1 = 5.20 g).

% Moisture Absorption (PMA)

To decide the PMA trial of the buccal films, consistently cut 1 cm in diameter across 3 films and after that set in a desiccator, keeping the RH at 79.5%. The films kept a side for 3 days, weighed and PMA was evaluated. The normal of 3 films was ascertained.

$$\% \text{ Moisture Absorption} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} X100$$

Swelling (%)

About 50 mL of pH 6.7 phosphate buffer included an altogether cleaned petri dish into which buccal films were put. Weight was determined by measuring changes in the film's mass at intervals of 15 minutes to 1-hour. Weight was determined by measuring changes in the film's mass at intervals of 15 minutes to 1-hour. The swelling rate was dictated by the equation,

$$\% S = \frac{X_t - X_0}{X_0} X100$$

Drug Content

About 1-mL of the formulation was put into a 100 mL volumetric flask, dissolved in distilled water and then the volume was adjusted to a final 100 mL using 6.7 phosphate buffer. This allowed for the continuous shaking and assessment of the drug concentration. The produced solution's absorbance was then measured at 254 nm.[19]

In-vitro permeation study

A diffusion cell with egg membrane, laboratory-designed, was used to test the formulation. In the experiment, 100 mL of newly generated simulated buccal fluid (SNF) at 35 ± 2°C was filled with 2 × 1 cm prepared buccal film was placed in the donor compartment. Using a magnetic stirrer, the contents of the receiver compartment were swirled. Under sink circumstances, 1 mL aliquots were taken out of the receiver compartment at 1, 2, 3, 4, 6, 8, 10 and 12 hours. After that, these samples were examined at 254 nm using a UV-visible spectrophotometer.[20-33]

RESULTS AND DISCUSSION

The calibration curve of memantine was performed by using a UV-visible spectrophotometer at 254nm. The regression coefficient value of memantine was found to be 0.995, which indicates a linear curve (Figure 1).

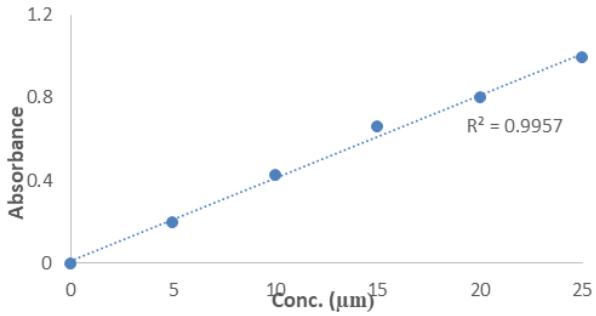

Figure 1: Standard curve of memantine

Physico-chemical properties

All the prepared formulations were tested for physicochemical properties, and the results are illustrated in Table 2.

It was thought that the resident time largely depended on the rate of dissolution of the polymer and that surface charge thickness and attach adaptability were required for bioadhesion. Because of their anionic nature, the films containing carbopol showed the strongest bioadhesive power. Because memantine films are bioadhesive, it is simple to keep them in the buccal cavity. Because the HPMC particles were smaller and more numerous, it was found that they had a greater surface area to come into contact with the bodily fluid film. PVP collection improved the bioadhesive quality, which could be related to van der Waals and hydrogen bond design. The results were displayed in Figure 2. In the F9 film, the most severe buccoadhesive quality was obtained. As a result, the substance of every formulation remained consistent. The mucoadhesive strength was determined by measuring the detachment stress, which is the force required to separate the formulation from the mucosal surface.

Ex-vivo Residence Time

The films that were reported for the ex-vivo residence period utilizing sheep mucosa are displayed in Figure 3. The sticky limit of the polymer utilized in the formulation is replicated in this test. Each film had a residency period that varied from 4.12 to 10.45 hours. Since all of the polymers were hydrogels, when they came into contact with the surface of physiological fluids, they expanded and created hydrophilic networks. The length of the ex-vivo residence is particularly connected to the swelling file. While F9 had the longest residence duration and the best formulation with delayed drug release, the polymer HPMC and chitosan displayed the most severe residence times.

Swelling index

After six hours, the buccal film swelling profiles in F9 were elevated. The presence of water-soluble polymers nearby could be the source of the increased swelling list. It has been determined that the fundamental cause of the polymer's mucoadhesive performance is its swelling nature. In six hours,

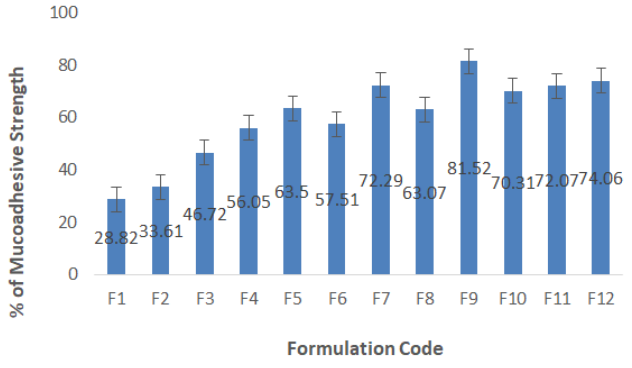

Figure 2: %of Mucoadhesive Strength

Table 2: Physico-chemical properties of prepared formulation

Formulation code	*Folding endurance*	*Thickness*	*%Moisture absorption (PMA)*	*%Swelling index*	*Drug content %*	*Mucoadhesive strength [g]*
F1	341 ± 4.021	0.46 ± 0.22	5.21 ± 0.04	49.53 ± 1.642	72.21 ± 1.028	28.82 ± 0.085
F2	323 ± 5.265	0.42 ± 0.14	6.32 ± 0.09	47.62 ± 1.428	76.78 ± 1.062	33.61 ± 0.042
F3	325 ± 3.254	0.43 ± 0.24	8.24 ± 0.02	48.82 ± 1.942	81.29 ± 1.434	46.72 ± 0.036
F4	291 ± 4.113	0.36 ± 0.65	7.32 ± 0.32	51.64 ± 1.042	83.37 ± 1.352	56.05 ± 0.091
F5	289 ± 4.521	0.39 ± 0.24	8.13 ± 0.03	49.84 ± 1.038	84.52 ± 2.431	63.50 ± 0.026
F6	321 ± 5.254	0.42 ± 0.19	9.21 ± 0.09	47.68 ± 1.047	85.43 ± 1.342	57.51 ± 0.039
F7	314 ± 4.353	0.44 ± 0.16	8.86 ± 0.07	51.41 ± 1.428	81.61 ± 1.561	72.29 ± 0.062
F8	306 ± 6.214	0.39 ± 0.15	7.18 ± 0.06	54.21 ± 1.428	79.25 ± 1.676	63.07 ± 0.081
F9	349 ± 4.432	0.38 ± 0.06	6.34 ± 0.08	58.63 ± 1.824	92.47 ± 1.692	81.52 ± 0.075
F10	327 ± 2.765	0.43 ± 0.02	5.12 ± 0.04	49.32 ± 1.064	82.69 ± 1.846	70.31 ± 0.083
F11	321 ± 2.642	0.46 ± 0.04	5.85 ± 0.02	51.82 ± 1.636	81.82 ± 0.064	72.07 ± 0.066
F12	294 ± 1.076	0.45 ± 0.03	6.93 ± 0.51	53.52 ± 1.21	79.35 ± 0.051	74.06 ± 0.047

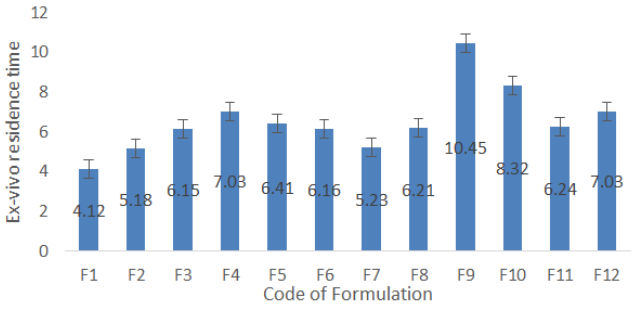

Figure 3: *Ex-vivo* residence time of F1-F12

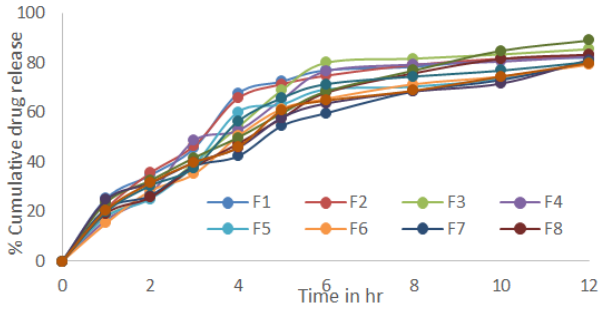

Figure 4: Swelling index of formulations F1-F12

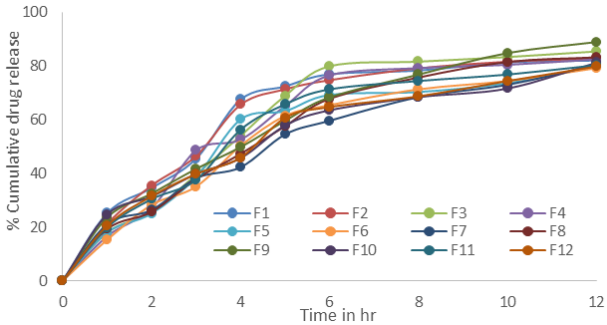

Figure 5: Zero-order release profile F1-F12

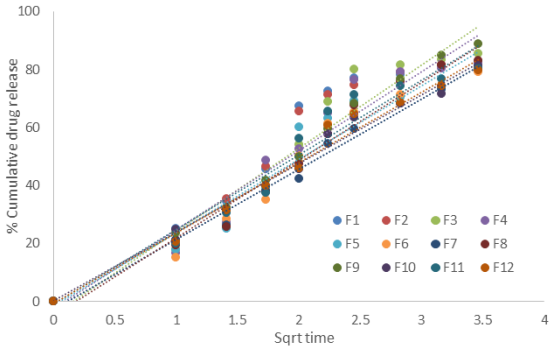

Figure 6: Higuchi kinetic profile of F1-F12

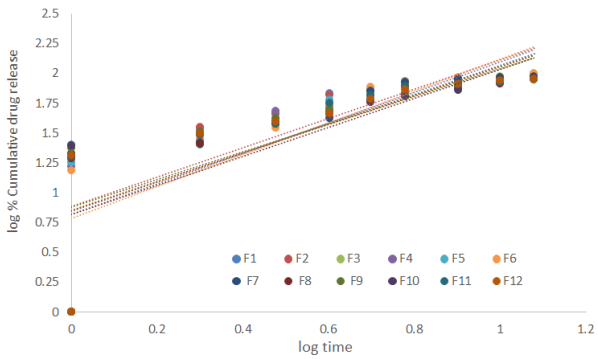

Figure 7: Korsmayer Peppas Plot of formulation F1-F12

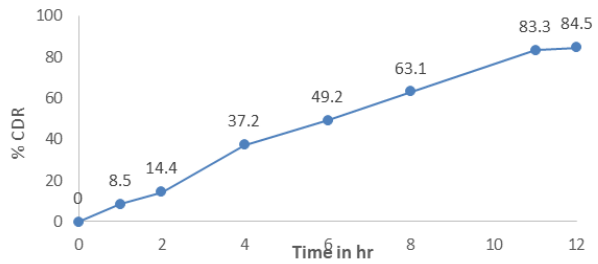

Figure 8: *Ex-vivo* permeation profile of optimized formulations (F9)

there was a greater rate of swelling, and the polymer gradually started to break down in the medium. When compared to HPMC and carbopol, the sodium CMC is thinner, which results in lower molecular binding pressures. Figure 4 displayed the swelling properties data graphically.

Among every one of the formulations, F9 indicated higher *ex-vivo* residence time. Hence, it was presumed that the *ex-vivo* resident time expanded with increment in the carbopol and chitosan fixations, what's more with HPMC& its relevant Figure 5.

All the formulations showing different release kinetic models are depicted in Figures 6 and 7.

The medication penetration was nearly the same in all of the formulations. For up to three hours, there was a significant rate of drug permeation. After that, it didn't change for up to six hours. *In-situ* gel compositions had a greater initial burst release. When compared to a formulation without carpool all formulations adding carbopol 934 demonstrated reduced burst release.

Ex-vivo Permeation

The film contains a higher quantity of carbopol and the F9 film's higher penetration rate of 84.5 is represented by the chitosan. This could be due to surface attachment despite hydrogen bond arrangement across the buccal mucosa, which causes rapid swelling of films containing chitosan and carbopol and delays the medication's release rate. The dosage was progressively increased over the course of 12 hours, from 8.5 to 84.5% (Figure 8). However, it was noted that cationic and anionic amino corrosive residues were present in the chitosan.

CONCLUSION

Out of all the films, F9 showed a longer duration of contact. Additionally, it was observed that the lengthening of the ex-vivo residence arrangement period increased with an increase in the fixations of chitosan and carbopol, as well as with HPMC in definitions. The polymer fraction of memantine and the compositions of the various buccal films determined the drug release rate, which was modest and occurred over a period of more than 12 hours. The optimal fixation blend of HPMC, carbopol, and chitosan polymers resulted in the most intense drug release from the buccal film for all of the polymers. At the end of the 12 hour period, the detailed F9 showed 88.05 ± 0.550. A proposal was made for the drug release design that would involve the dissolution and diffusion of the drug from all buccal films to the general discharge component.

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REFERENCES

1. Patel H, Patel P, Brahmbhatt T, Suthar M. In Situ Gelling System-A Review. Journal of Chemical and Pharmaceutical Research. 2011;3(6):217-221.
2. HB N, Bakliwal S, Pawar S. In-situ gel: new trends in controlled and sustained drug delivery system. International Journal of Pharm Tech Research. 2010;2(2):1398-1408.
3. Allen C. Humphrey P, Ferrari M, Olesen, J. Rizatriptan: clinical update. In: The triptans: novel drugs for migraine. New York: Oxford University Press. 2001;1:199-205.
4. Anthony CM, Osserton MD, Widdip B. In: Clark's analysis of drugs and poison. Regis, L. Borset. London. 2004;1:1540.
5. Saravanakumar K, Nagaveni P, Peram DR, Medarametla KB, Kumar TC, Balaji A. Formulation and Evaluation of Meloxicam pH Induced In-situ Gels.International Journal of Clinical Pharmacokinetics and Medical Sciences. 2021; 1(1): 23-27. https://doi.org/10.26452/ijcpms.v1i1.187
6. Sanders-Bush E, Mayer SE. 5-Hydroxytryptamine (serotonin): receptor agonists and antagonists. The Pharmacological Basis of Therapeutics. Goodman &, Gilman's McGaw-Hill. 2006:297-315.
7. Madhu Medabalimi, Saravanakumar K, Satyanarayana S.V. Development and Validation of Stability Indicating RP-HPLC Method for Quantitative Estimation of Safinamide Mesylate in Bulk and its Tablet Dosage Form. Current Trends in Biotechnology and Pharmacy. 2022; 16(2): 50-59.
8. Medabalimi M, Kasimedu S, Satyanarayana SV. UPLC Method Development And Validation For The Simultaneous Estimation Of Cytarabine And Daunorubicin In Pharmaceutical Dosage Form. Journal of Pharmaceutical Negative Results. 2022 :7816-1725. https://doi.org/10.47750/pnr.2022.13.S07.948
9. Shinde JV, Mali KK, Dias RJ, Havaldar VDand Mahajan NS. In-situ Mucoadhesive Nasal Gels of Metoclopramide hydrochloride: Preformulation and Formulation Studies. Journal of Pharmacy Research. 2008; 1(1):88-96.
10. Saravanakumar K, Radhika C, Nagaveni P, Nethra Vani G, Lakshmi Prasanna T, Rajitha I, Development and Characterization of Occular Delivery of Moxifloxacin In-Situ Gel, International Journal of Current Trends in Pharmaceutical Research. 2016; 4(1): 35–40.
11. Ramesh B, Saravanakumar K, Nagaveni P. A review on buccal drug delivery system. International Journal of Research in Pharmaceutical Sciences. 2014; 5(3): 2000-2004.
12. Ricci EJ, Bentley MV, Farah M, Bretas RE, Marchetti JM. Rheological characterization of Poloxamer 407 lidocaine hydrochloride gels. European Journal of Pharmaceutical Sciences. 2002;17(3):161-167. https://doi.org/10.1016/S0928-0987(02)00166-5
13. Nisha GS, Maithil P, Charyulu RN. Formulation and Development of Nasal in-situ Gels of Triptans for Anti Migraine Activity. International Journal of Research in Pharmaceutical and Biomedical Sciences. 2012; 3(2):862-870.
14. Pisal SS, Paradkar AR, Mahadik KR, Kadam SS. Pluronic gels for nasal delivery of Vitamin B12. Part I: preformulation study. International journal of pharmaceutics. 2004;270(1-2):37-45. https://doi.org/10.1016/j.ijpharm.2003.10.005
15. Choi HG, Jung JH, Ryu JM, Yoon SJ, Oh YK, Kim CK. Development of in situ-gelling and mucoadhesive acetaminophen liquid suppository. International journal of pharmaceutics. 1998;165(1):33-44. https://doi.org/10.1016/S0378-5173(97)00386-4
16. Mahajan HS, Gattani SG. Gellan gum based microparticles of metoclopromide hydrochloride for intranasal delivery: development and evaluation. Chemical and Pharmaceutical Bulletin. 2009;57(4):388-392. https://doi.org/10.1248/cpb.57.388
17. Yong CS, Choi JS, Quan QZ, Rhee JD, Kim CK, Lim SJ, Kim

KM, Oh PS, Choi HG. Effect of sodium chloride on the gelation temperature, gel strength and bioadhesive force of poloxamer gels containing diclofenac sodium. International journal of pharmaceutics. 2001;226(1-2):195-205. https://doi.org/10.1016/S0378-5173(01)00809-2

18. Saravanakumar K, Jayachandra Reddy P, Chandra Sekhar KB. Formulation development and characterization of Naproxen sodium-loaded mucoadhesive microspheres. Journal of Pharmaceutical Science and Research. 2012; 4(2): 1709-1715.
19. Majithiya RJ, Ghosh PK, Umrethia ML, Murthy RS. Thermoreversible-mucoadhesive gel for nasal delivery of sumatriptan. AAPS pharmscitech. 2006 Sep;7:E80-86. https://doi.org/10.1208/pt070367
20. Singh S. Drug stability testing and shelf-life determination according to international guidelines. Pharmaceutical technology. 1999;23(6):68-88.
21. Kumar SK, Reddy JP, Sekhar CK. Formulation of neostigmine bromide-loaded mucoadhesive microspheres by emulsification-internal gelation technique and evaluation of their gastro-retentive capabilities. Journal of Pharmaceutical Sciences and Research. 2011 Nov 1;3(11):1544-1551.
22. Devhare LD and Gokhale N. Antioxidant and Antiulcer Property of Different Solvent Extracts of Cassia Tora Linn. Research Journal of Pharmacy and Technology. 2022;15(3);1109-1113. http://dx.doi.org/10.52711/0974-360X.2022.00185
23. Tiwari R, Mishra J, Devhare LD and Tiwari G. An updated review on recent developments and applications of fish collagen. Pharma Times. 2023;55(6):28-36
24. Adimulapu AK, Devhare LD, Anasuya Patil A, Chachda NO, G. Dharmamoorthy. Design and Development of Novel Mini Tablet Cap Technology for the Treatment of Cardiovascular Diseases. International Journal of Drug Delivery Technology. 2023;13(3):801-806. DOI: 10.25258/ijddt.13.3.04
25. Chawla A, Devhare LD, Dharmamoorthy G, Ritika, Tyagi S. Synthesis and In-vivo Anticancer Evaluation of N-(4-oxo-2-(4-((5-aryl-1,3,4 thiadiazole-2yl) amino) Phenyl thiazolidine-3-yl) Benzamide derivative. International Journal of Pharmaceutical Quality Assurance. 2023;14(3):470-474. DOI: 10.25258/ijpqa.14.3.02
26. Gnana RPM, Devhare LD, Dharmamoorthy G, Khairnar MV, Prasidha R. Synthesis, Characterisation, Molecular Docking Studies and Biological Evaluation of Novel Benzothiazole Derivatives as EGFR Inhibitors for Anti-breast Cancer Agents. International Journal of Pharmaceutical Quality Assurance. 2023;14(3):475-480. DOI: 10.25258/ijpqa.14.3.03
27. Sonule M, Devhare LD, Babu MN, Gunjal SD, Varalaxmi S. Microemulgel-based Hydrogel of Diclofenac Sodium using Lipidium sativum as a Gelling Agent. International Journal of Drug Delivery Technology. 2023;13(4):1235-1239. DOI: 10.25258/ijddt.13.4.19
28. Shriram BK, Devhare LD, Mehrotra A, Deokar SS, Singh SP. Formulation and Evaluation of Mosquito Repellent Stick. International Journal of Drug Delivery Technology. 2023;13(4):1283-1286. http://dx.doi.org/10.25258/ijddt.13.4.26
29. Choudhary RK, Beeraka S, Sarkar BK, Dharmamoorthy G, Devhare L. Optimizing Verapamil Hydrochloride In-situ Delivery: A Strategic Formulation Approach using Box-Behnken Design for Enhanced Performance and Comprehensive Evaluation of Formulation Parameters. International Journal of Drug Delivery Technology. 2024;14(1):61-70. DOI: 10.25258/ijddt.14.1.11
30. Kumar KK, Kiran V, Choudhary RK, Devhare LD, Gunjal SD. Design Development and Characterization of Nicardipine Solid Lipid Nano-Particulars. International Journal of Drug Delivery Technology. 2024;14(1):71-78. DOI: 10.25258/ijddt.14.1.12
31. Priya MGR, Prasanth LML, Devhare LD, Yazdan SK, Gunjal S. Synthesis, DNA Binding, Molecular Docking and Anticancer Studies of Copper (II), Nickel (II), and Zinc (II) Complexes of Primaquine-based Ligand. International Journal of Pharmaceutical Quality Assurance. 2024;15(1):69-75. DOI: 10.25258/ijpqa.15.1.10
32. Uplanchiwar VP, Raut SY, Devhare LD, et al. Pharmacological Assessment of Antiulcer Activity of Gloriosa Superba Linn Tubers In Experimentally Induced Gastric Ulcers. Journal of Medical Pharmaceutical and Allied Science. 2021;10(3);2852-2856.
33. Tiwari G, Gupta M, Devhare LD, & Tiwari R. Therapeutic and Phytochemical Properties of Thymoquinone Derived from Nigella Sativa. Current Drug Research Reviews. 2024;16(2):145-156. https://doi.org/10.2174/2589977515666230811092410