International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 22s, 2025
https://theaspd.com/index.php

Design and Characterization of Nasal Mucoadhesive Microspheres Loaded with Mucuna Pruriens

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Abstract:
Objective: *The present study was conducted to formulate and evaluate nasal mucoadhesive microspheres containing Mucuna pruriens (MP) for the treatment of Parkinsonism, aiming to merge the advantages of prolonged drug delivery with mucoadhesive targeting. Using the orifice- ionic gelation technique, nine microsphere formulations were prepared by varying the concentrations of polymers such as sodium alginate, hydroxypropyl methylcellulose (HPMC), and methyl cellulose (MC). The formulations were assessed for various physicochemical properties including particle size, percentage yield, drug content, entrapment efficiency, moisture content, mucoadhesive strength, and drug release behavior. Analytical techniques like FT-IR and SEM were employed to confirm structural integrity and surface morphology. FT-IR spectra revealed the presence of key functional groups, while the microspheres displayed spherical shape and good flowability. The mucoadhesive microspheres enhanced the drug's residence time at the absorption site, thereby improving bioavailability. Among the formulations, F9 showed the most desirable characteristics, including strong mucoadhesion, effective drug entrapment, and a sustained release profile lasting up to 10 hours. These results suggest that F9 is a promising candidate for the controlled nasal delivery of Mucuna pruriens.*
Keywords: *Mucoadhesive Microspheres, Parkinsonism, Mucuna Pruriens, Mucoadhesion test, In-vitro drug release studies.*

INTRODUCTION:

Microspheres are small, spherical particles that usually have a diameter of one to a thousand micrometers. Microspheres are also known as microparticles. Mucoadhesive microspheres are a crucial part of a novel drug delivery technique. It is possible to get around the microspheres' brief residence time at the absorption site by giving them bioadhesion properties and producing bioadhesive microspheres. Mucoadhesive microspheres help overcome the relatively short GI residence period and improve localization of oral controlled or sustained release drug delivery systems by closely adhering to the mucous layer and accurately guiding the drug to the absorption site.

The main objective of a novel oral controlled drug delivery system design should be to raise the bioavailability of medications in a predictable manner. There are some obstacles, nevertheless, such as the extremely irregular character of the gastro emptying process and the difficulty of identifying the drug delivery mechanism inside the gastro intestinal tract. The efficacy of the administered dose may be diminished if the drug delivery system releases the medication insufficiently in the major absorption zone, which is the stomach or upper portion of the intestine. A drug delivery method that is limited to a specific region of the gastrointestinal tract improves the proximity and duration of contact between a drug-containing polymer and the mucus surface because of its mucoadhesiveness. There are numerous advantages to this type of drug delivery system particularly for drugs that have stability problems or an absorption window2. Research on Mucuna Pruriens as a Parkinson's disease treatment has been conducted because of its high concentration of L-DOPA and other phytochemicals. Usually, an extract based on L-DOPA dose2 is administered. Because L- DOPA is a treatment for Parkinson's disease, researchers compared the effects of Mucuna pruriens to pharmaceutical L-Dopa and other drugs for this purpose.

Native to India and other tropical areas, the velvet bean, or Mucuna pruriens Linn. (Fabaceae), is an annual climbing legume. There are fifteen different species of Mucuna in the wild in India. Due to the general awareness of the plant's advantageous medicinal properties, Mucuna is required in the Indian pharmaceutical sector. When it comes to Parkinson's disease, M. pruriens is the real thing, and it works incredibly well. The seed has been linked to several medicinal benefits, including as those for blood sugar,

cancer, inflammation, libido, Parkinson's disease, and infection. Thus, evaluating the safety of the phytochemicals included in herbal plants is essential.

Research Design Methodology

This study follows a quantitative research design. A descriptive survey method was employed to collect data, focusing on the perceptions of secondary school teachers in Lahore.

Population and Sample

The target population included secondary school teachers from private schools in Lahore that have implemented interactive whiteboards. A sample of 100 teachers was selected through convenient sampling.

Instrumentation

A structured questionnaire was used to gather data. The questionnaire included both closed-ended and Likert-scale items designed to measure teachers' perceptions, benefits experienced, and challenges encountered in using IWBs.

Data Collection: The researcher distributed questionnaires directly to the selected schools. Respondents were briefed about the study's purpose, and their participation was voluntary. All responses were kept confidential.

Data Analysis

Collected data were analyzed using descriptive statistics, primarily frequencies and percentages. The results were presented in tabular form to provide a clear understanding of the findings

Table 1 Composition of Mucoadhesive microspheres of Mucuna pruriens

Ingredients (mg)	Formulation Code								
	F1	F2	F3	F4	F5	F6	F7	F8	F9
Mucuna pruriens	100	100	100	100	100	100	100	100	100
Sodium alginate	100	200	300	100	200	300	100	200	300
Hydroxypropyl methyl cellulose (HPMC)	-	-	-	50	100	150	50	100	150
Methylcellulose (MC)	-	-	-	-	-	-	100	100	100
Calcium chloride (%)	5	5	5	5	5	5	5	5	5

Evaluation of Mucoadhesive microspheres of Mucuna pruriens

Drug polymer compatibility

The qualitative analysis of the active principles of Mucuna pruriens seed extract was done by FTIR method. IR spectroscopy was used to observe drug and polymer interaction. By using the KBr dispersion method, FTIR studies of pure Mucuna pruriens and a physical mixture of Mucuna pruriens with polymers were conducted[6].

Particle Size Determination

The microspheres' particle size distribution was examined using a set of conventional sieves to establish their composition. Particle sizes between 50 and 1500 m are estimated using the sieve method. This approach directly determines weight distribution. The sifting process can be advantageous for the creation of dosage forms in the shape of tablets and spheres.

Percentage Yield

The total number of microspheres produced was measured, and the yield percentage was assessed[8].

$$\text{Percentage yield} = \frac{\text{Practical yield}}{\text{Theoretical yield}}$$

X 100

Scanning electron microscopy (SEM):

Examined the microspheres using scanning electron microscopy to measure the size and shape of the microspheres. They were coated with gold film, fitted with an ion spiller and gold target with resolutions of 3 nm (30 KV HV Mode), 10 nm (30 KV HV Mode), and 40 nm, and directly mounted to the SEM sample stub using double-sided sticky tape (30 LV Mode).

Drug content

Mucuna pruriens' standard curve was performed using a UV-VIS spectrophotometer at a maximum wavelength of 280 nm in pH 6.8. (UV-1700, Shimadzu Corporation). It followed Beer's rule. The concentration range used for the calibration curve was 5–25 g/ml.

Entrapment efficiency

A 3 ml solution of sodium citrate solution (1%w/v) was used to fully dissolve 100 mg of Mucuna pruriens microspheres from each batch. 7 ml of methanol were added to the aforementioned solution to dissolve the Mucuna pruriens. By measuring the filtrate's absorbance at 280 nm following an appropriate dilution by a UV-Visible spectrophotometer, the concentration of the medication was determined. Using the procedure, encapsulation effectiveness was determined[11].

$$\text{Entrapment efficiency} = \frac{\text{Estimated \% drug content in microspheres}}{\text{Theoretical \% drug content in microspheres}} X100$$

Percentage moisture content:

The Mucuna pruriens -loaded microspheres were assessed for moisture content in order to estimate their hydrophilic nature. The microspheres, which initially weighed (w1), were maintained at 37° C in a desiccator with calcium chloride for 24 hours. When there was no longer any change in the sample's weight, the final weight (w2) was recorded.

$$\text{Moisture Percentage} = \frac{W1 - W2}{W2} 100$$

In -vitro wash off test for mucoadhesion:

The ability of the Mucuna pruriens microspheres to adhere to mucous membranes was evaluated using the wash-off method, an in-vitro adhesion testing procedure. Using poly cyanoacrylate adhesive, freshly removed sheep intestinal mucosa samples (4 x 5 cm) were mounted onto glass slides (3 x 1 inch)[13]. Two glass slides were joined together with an appropriate sample of each wet-rinsed tissue, and then the support was instantly attached onto the arm of a USP pill dissolving test device. In the course of the disintegration test apparatus's operation, the tissue sample was slowly and consistently moved up and down in a 400 ml vessel of test fluid heated to 37 °C. The machine was shut off after one hour and then every hour for the next eight hours so that the amount of microspheres still adhered to the tissue could be counted.

In- vitro drug release studies

The USP Type-2 Paddle Operation 37±0.5^{0}c was used to conduct an in-vitro drug release investigation. The temperature was held constant at 37°C throughout the trial. Microspheres of Mucuna pruriens in an amount equivalent to 100 mg were kept in a basket-shaped apparatus and dissolved in 900 ml of (pH 6.8) in a 1000 ml dissolving flask. Using a syringe equipped with a prefilter, 2 ml of samples were taken out at regular intervals and put back into the dissolution flask containing pH 6.8. When the sample had been diluted as needed with fresh medium, the absorbance was measured at 280 nm (pH 6.8). There were three duplicates of each study.

Ex-vivo Permeation studies through Nasal mucosa

Permeation experiments were conducted using nasal mucosal tissue with the aid of a modified Franz diffusion cell setup. The entire apparatus was maintained at a constant temperature of 37 ± 2°C throughout the procedure. A phosphate buffer solution (pH 6.8) served as the medium in the receptor compartment, which was continuously stirred using a magnetic stirrer. At predetermined time intervals, aliquots were withdrawn from the receptor phase and immediately replenished with an equal volume of fresh buffer solution. The amount of drug present in the collected samples was quantified after performing appropriate dilutions.

Stability study:
The formulation (F9) was kept in aluminium foils for three months at accelerated conditions (40. °C ± 2 C at 75% RH ±5% RH). After the first, second, and third months, the samples were withdrawn. The samples' drug content and in vitro drug release were examined.

RESULTS AND DISCUSSION:
Drug-polymer compatibility
Fourier transform infrared spectroscopy (FT-IR)
IR spectra of individual Mucuna pruriens and the combination of drug with polymers were shown in figure 1 (A-D). An IR spectrum of pure Mucuna pruriens showed the peaks 3648 cm1 (O-H stretching), 3221-3101 cm1 (N-H Stretching), 2982-2937cm1 (C-H Stretching), 1354-1265cm1 (C-O stretching), 1428-1368cm1 (C-H bending(in plane)), 1340 cm1 (C-C stretching) ,These peaks can be considered as characteristic peaks of Mucuna pruriens and there was no significant change was noticed in IR spectra of Mucuna pruriens along with polymers as shown in the figure (B-D). Among the functional groups observed in the extracts, OH group was found in the seed of
M. pruriens. As OH group has got the ability of forming hydrogen bonding capacity, presence of OH group indicates the higher potential towards inhibitory activity against microorganisms. **Percentage Yield:**
The total number of microspheres that were obtained, weighed, and tested for percentage yield. Out of all the formulations prepared, F9 demonstrated the highest percentage yield (89.48%) represented in table 1.
Particle Size Determination:
By analyzing the average microsphere particle size for each formulation, standard sieves were used in the sieving procedure. According to the results values, the formulation F9 had produced particles with a smaller average size (647.38µm) than the other formulations represented in table 2.
Drug content estimation
For all of the formulations (F1 to F9), the drug content of microspheres was determined, and values are shown in Table 3. In comparison to the other prepared formulations, formulation F9 had the highest drug content.
Entrapment efficiency:
For all of the formulations (F1 to F9), the entrapment efficiency of microspheres was determined, and values are shown in the table (3). Formulation F9 had the highest entrapment efficiency (88.12%) in compared to other formulations
Percentage moisture content:
For all of the formulations (F1 to F9), the percentage moisture content was calculated using a desiccator containing calcium chloride at 37°C for 24 hours. The final weight was calculated and contrasted with the starting weight, Table 4 represented the values. Formulation F9 was determined to be the best one by comparing other formulations. The moisture content in the formulation F9 was lower. The order was F9<F8<F6<F7<F5<F4<F3<F2<F1.
Scanning electron microscopy (SEM):
Scanning electron microscopy was used to observe the microspheres. A vacuum system is attached to the SEM equipment, which has resolutions of 25 nm and 100 nm. Scanning electron microscopy revealed that the Mucuna pruriens microspheres were consistently dispersed and spherical in shape represented in figure 2.
In -vitro wash off test for mucoadhesion:
Table 5 shows the results of the wash-off tests for mucoadhesion for all formulations (F1 to F9) In the in-vitro wash off test, microspheres with a mucoadhesive polymer and alginate coating demonstrated good mucoadhesive characteristics. At pH 6.8, the wash-off test went more quickly (stomach pH). It was demonstrated that the degree of hydration, solubility, and mucoadhesion of the polymers was significantly influenced by the pH of the medium. With more than 63.28% retention for 8 hours in pH 6.8, the wash off test results showed that the formulation F9 exhibited very good mucoadhesive characteristics.
In- vitro drug release studies:
Studies on the in vitro release of mucoadhesive microspheres were conducted using pH 6.8 as the dissolving media and a spectrophotometric measurement of the drug absorbance at 280 nm. With formulation 9, there was a greater medication release. According to the type and composition of the polymer, using mucoadhesive microspheres, the in-vitro drug release varied. By increasing concentrations of more

hydrophilic polymers, it was discovered that the mucoadhesive microspheres released more drugs. Among the formulations (F1 to F9), F9 was shown to be the most effective. In vitro drug release of all formulations was shown in figure 3, and the values were reported in table 6. Formulation F9's in-vitro drug release was 81.76% over a period of 10 hours. To understand the release kinetics of Mucuna pruriens from these mucoadhesive microspheres, data from the in vitro release were fitted to several equations and kinetic models. The kinetic models that were applied were the Higuchi release, zero-order equation, first-order equation, and Korsemeyer & Peppas models. The Korsemeyer and Peppas model had the best fit with the highest correlation coefficient (r = 0.9907). All of the formulations' "n" values are smaller than 0.5, which indicates that they all adhere to the Fickian model of drug release represented in the table 8.

Ex-vivo Permeation studies through Nasal mucosa

In table 7 Ex-vivo permeation studies through nasal mucosa of all the formulations represented and the formulation F9 shows the cumulative highest nasal permeation (80.16%) at the end of 10 hours while compared to other formulations. The order of all the formulations based on their ex- vivo nasal permeation is represented as F9>F8>F7>F6>F5>F4>F3>F2>F1.

Stability Study:

Investigations on mucoadhesive microspheres that had been chosen and optimised were done to determine their short-term stability. The stability results showed that neither the drug content nor in-vitro drug release had undergone any significant alterations. The optimized formulation (F9) drug content and in-vitro drug release values are reported in table 9, and the findings are represented graphically in figure 4.

Table1: Percentage yield of all microspheres formulations

S. No	Formulation Code	Percentage yield (%)
1.	F1	74.32
2	F2	78.09
3	F3	74.64
4	F4	79.89
5	F5	82.17
6	F6	72.18
7	F7	67.44
8	F8	86.43
9	F9	89.48

Table2: Average particle size of microspheres

S. No	Formulations	Average particle size (µm)
1	F1	651.38±1.45
2	F2	695.18±0.52
3	F3	725.64±2.54
4	F4	747.28±0.81
5	F5	763.58±0.34
6	F6	798.56±0.44
7	F7	667.85±1.14
8	F8	698.48±0.44
9	F9	647.38±1.94

*All values are expressed as mean ± S.D. n=3

Table 3: Drug content and Entrapment efficiency

S. No	Formulations	Mean drugcontent (%) ± S.D*	Entrapment efficiency (%)
1	F1	43.22±0.76	71.89
2	F2	37.44±1.62	72.16
3	F3	39.82±1.45	81.75
4	F4	41.72±1.92	84.16
5	F5	42.19±0.78	79.39
6	F6	40.14±2.34	83.18
7	F7	35.06±0.85	72.12
8	F8	33.12±1.92	78.67
9	F9	47.12±0.78	88.12

*All values are expressed as mean ± S.D. n=3

Table 4: Percentage moisture content of microspheres

S. No	Formulations	Percentage moisture content (% ± S.D)
1	F1	8.723±0.234
2	F2	7.637±0.040
3	F3	5.876±0.078
4	F4	4.158±0.121
5	F5	3.529±0.132
6	F6	3.069±0.050
7	F7	2.516±0.080
8	F8	1.944±0.138
9	F9	1.116±0.130

*All values are expressed as mean ± S.D. n=3

Table 5: Data of in- vitro wash off test to assess mucoadhesive properties ofmicrospheres

Formulations	1 hour	2 hour	4 hour	6 hour	8 hour
F1	96.77±0.14	89.45±0.45	69.14±0.98	57.35±1.78	42.68±1.78
F2	95.36±1.46	86.31±0.98	79.12±0.18	62.86±1.24	40.96±0.23
F3	98.89±0.17	83.82±1.45	77.99±0.45	67.96±1.11	47.86±0.57
F4	98.12±0.13	87.61±1.12	73.67±0.56	59.67±1.45	45.29±1.32
F5	95.99±1.98	83.82±0.56	78.19±0.89	55.18±0.89	53.86±0.12
F6	97.44±1.56	92.45±0.58	83.92±1.57	67.64±0.97	55.14±1.45
F7	98.16±0.45	89.73±0.13	83.79±0.98	65.16±1.78	45.19±0.59
F8	96.78±1.87	92.81±0.19	79.17±1.67	59.19±1.55	43.18±1.12
F9	99.94±0.55	96.86±1.13	93.18±0.98	85.32±1.67	63.28±0.32

*All values are expressed as mean ± S.D. n=3

Table 6: Data of In-vitro drug released profile of Mucuna Pruriens loaded nasal mucoadhesive microspheres*

S. No	Time in hours	Formulations								
		F1	F2	F3	F4	F5	F6	F7	F8	F9
1	1	13.89±0.11	10.68±1.54	17.42±1.04	11.58±1.54	15.46±1.56	12.65±0.45	18.35±1.78	16.93±0.45	19.84±1.54
2	2	23.36±1.23	16.98±1.89	21.54±1.66	17.29±0.61	19.75±1.05	20.67±0.15	25.90±1.96	22.76±0.55	26.72±1.45
3	3	29.07±1.54	25.37±0.54	27.65±0.20	21.45±0.02	23.67±1.51	26.74±1.63	30.05±0.12	28.23±0.56	31.36±1.52
4	4	36.64±1.56	32.46±1.65	31.56±1.53	28.87±0.91	29.56±1.55	33.45±1.55	39.45±0.56	35.98±0.22	38.43±0.01
5	5	42.34±0.57	45.36±0.22	39.78±1.01	35.47±0.78	34.78±0.45	39.87±1.23	44.89±1.56	41.87±1.51	46.64±0.12
6	6	49.07±0.23	47.48±0.55	48.97±0.50	41.68±0.51	40.56±0.61	43.75±1.25	52.98±3.45	48.24±1.02	51.28±0.65
7	7	53.03±1.54	50.67±0.23	51.87±1.21	48.89±0.05	46.78±0.49	49.56±0.61	59.56±1.56	52.76±1.55	57.14±0.54
8	8	61.96±1.45	56.89±1.55	58.16±0.54	52.98±0.07	54.81±0.61	53.23±0.74	64.87±1.26	59.56±1.16	66.49±1.55
9	9	66.76±0.77	61.87±0.54	64.89±0.26	59.89±0.07	63.46±1.54	65.56±0.07	69.90±0.16	67.87±1.55	72.38±0.65
10	10	69.26±0.54	65.08±1.54	71.08±0.50	63.47±0.52	67.89±0.91	70.45±0.21	74.13±1.51	76.12±1.16	81.76±0.55

*All values are expressed as mean ± S.D. n=3

Table 7: Data of ex vivo drug released profile of Mucuna Pruriens loaded nasal mucoadhesive microspheres*

S. No	Time in hours	Formulations								
		F1	F2	F3	F4	F5	F6	F7	F8	F9
1	1	12.13±0.54	11.24±0.49	16.12±1.67	12.28±0.59	14.76±0.56	11.15±1.45	17.35±1.78	17.13±0.75	18.94±0.54
2	2	22.76±0.22	15.81±1.29	20.41±1.56	18.69±0.71	20.15±1.95	19.78±1.15	24.93±1.36	23.16±0.85	25.82±0.45
3	3	28.17±0.26	24.57±0.84	26.25±0.50	20.95±0.32	22.17±1.51	25.34±1.93	29.15±0.32	27.13±0.36	30.16±1.72
4	4	35.14±1.56	30.36±1.75	32.56±1.58	29.77±0.61	30.76±1.65	32.15±1.35	38.15±0.56	34.58±0.42	39.13±1.01
5	5	41.14±0.45	44.26±1.22	38.28±1.81	34.17±0.98	35.88±0.35	40.27±1.43	45.19±0.56	43.17±1.51	47.84±1.12
6	6	50.27±0.32	48.78±1.55	49.57±0.80	42.88±0.31	41.66±0.71	44.55±1.35	53.68±1.45	49.44±1.72	52.98±1.65
7	7	54.03±1.74	51.57±0.34	52.57±1.91	49.69±0.25	47.28±0.99	50.46±1.61	60.16±1.66	53.96±1.55	58.24±1.54

8	8	62.86±1.56	57.19±1.65	57.16±0.59	53.18±0.57	55.91±0.31	54.93±0.34	65.73±1.96	60.76±1.16	67.99±0.55
9	9	65.61±1.77	61.87±0.84	64.89±0.56	59.89±0.87	63.46±1.64	65.56±1.07	69.90±011.6	67.87±1.55	72.38±0.85
10	10	67.16±1.59	64.48±1.59	70.28±0.20	62.12±0.72	66.19±0.41	69.15±1.21	73.23±1.58	76.92±2.16	80.16±1.55

*All values are expressed as mean ± S.D. n=3

Table 8: In-vitro drug released kinetics studies of all formulations

Formulation code	Zero order R^2	First order R^2	Higuchi R^2	Korsemeyer Peppas		Best fit mode
				R^2	n	
F1	0.9621	0.9501	0.9723	0.9908	0.432	Peppas
F2	0.9650	0.9705	0.9663	0.9909	0.456	Peppas
F3	0.9900	0.9471	0.9530	0.9985	0.402	Peppas
F4	0.9503	0.8439	0.9782	0.9908	0.485	Peppas
F5	0.9592	0.8811	0.9729	0.9903	0.365	Peppas
F6	0.9622	0.9307	0.9684	0.9903	0.462	Peppas
F7	0.9540	0.8611	0.9770	0.9901	0.398	Peppas
F8	0.9597	0.9162	0.9756	0.9907	0.441	Peppas
F9	0.9647	0.9609	0.9663	0.9907	0.356	Peppas

Table 9: Data of stability studies of formulation (F9)

Characteristics	Initials*	1 month*	2 month*	3 month*
Drug content (%)	47.12±0.78	46.92±0.18	46.62±3.46	45.84±0.03
In-vitro drugreleased	81.76	81.26	81.12	81.04

*All the values are expressed as mean± S.D., n=3

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 22s, 2025
https://theaspd.com/index.php

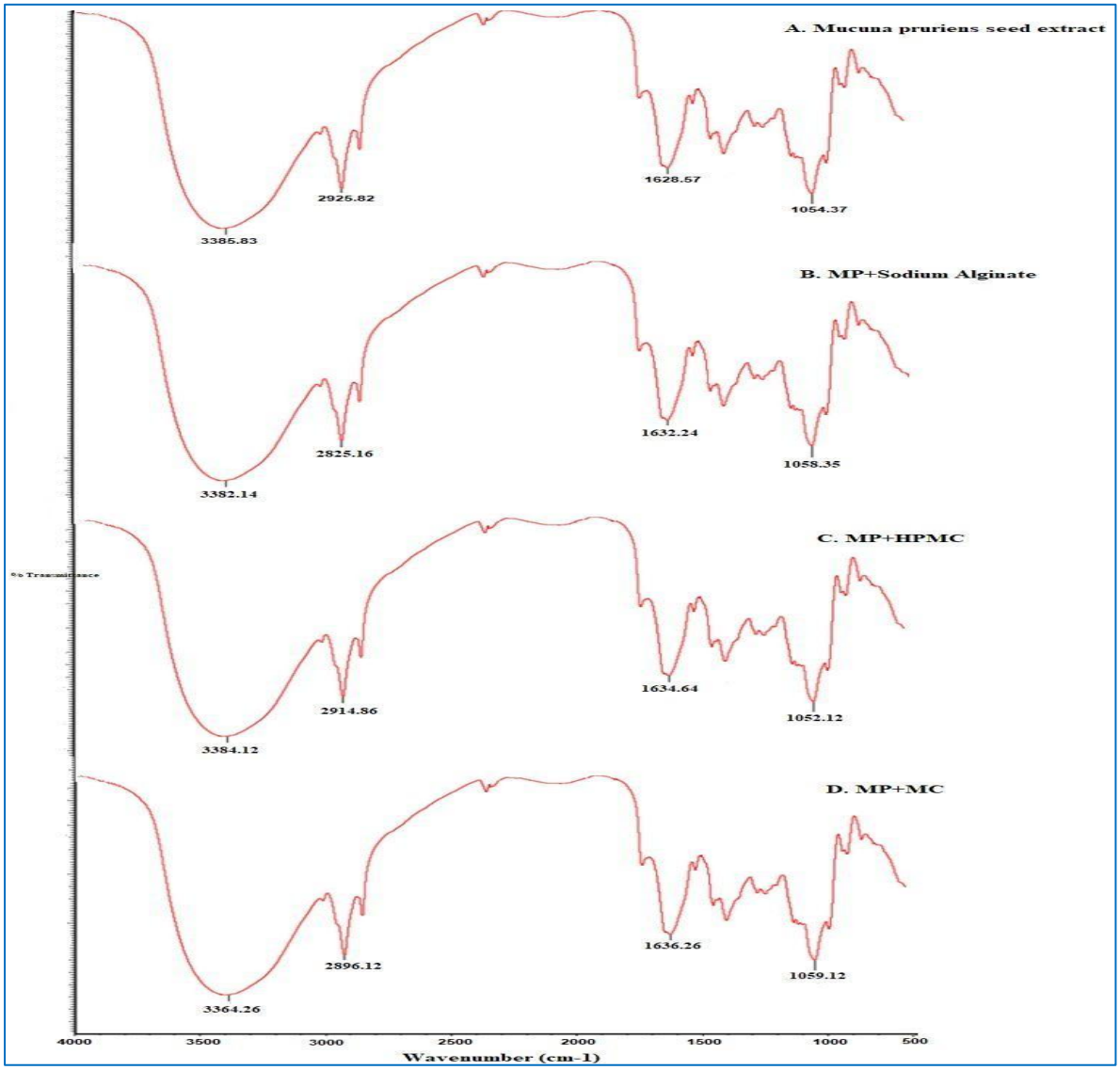

Figure 1: FT-IR Spectroscopic analysis of A. Mucuna pruriens (MP) seed extract, B. MP with Sodium alginate (SA), C. MP with Hydroxypropyl methylcellulose (HPMC) D. MP with Methylcellulose (MC)

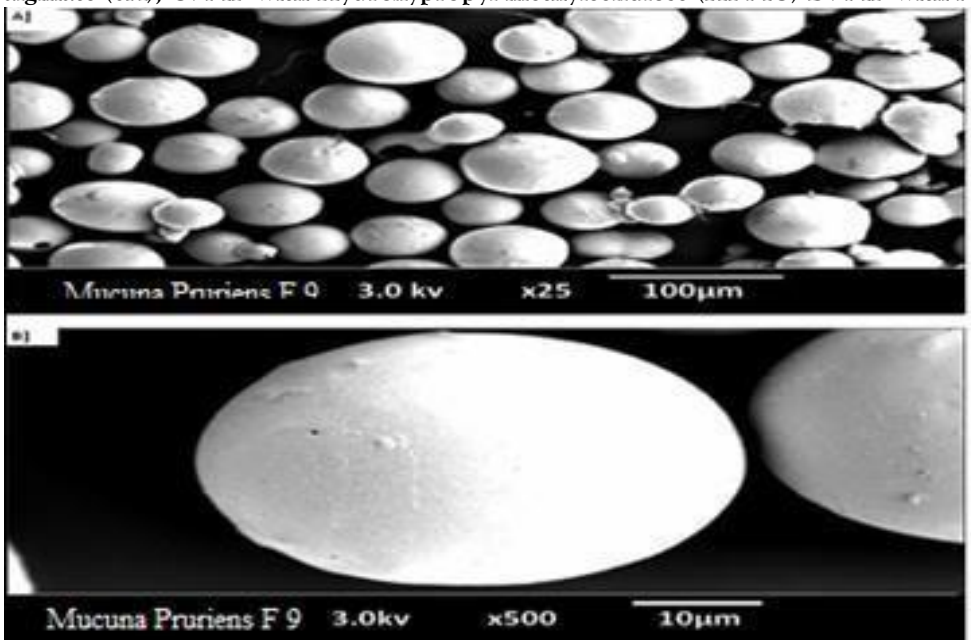

Figure 2: Scanning electron microscopy of Mucuna Prurien loaded Sodium Alginate and Methylcellulose (A. 100µm, B. 10µm

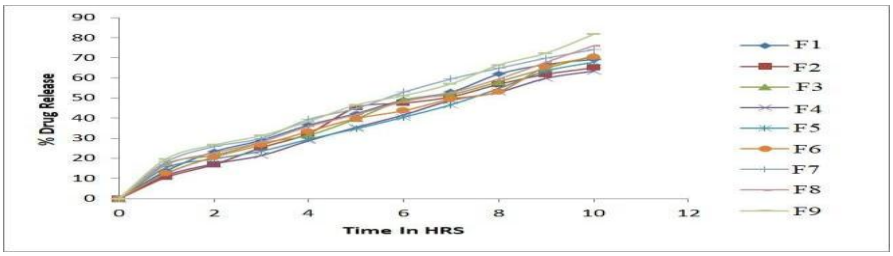

Figure 3: Zero order plot for comparison of in- vitro drug released for formulations F1 to F9

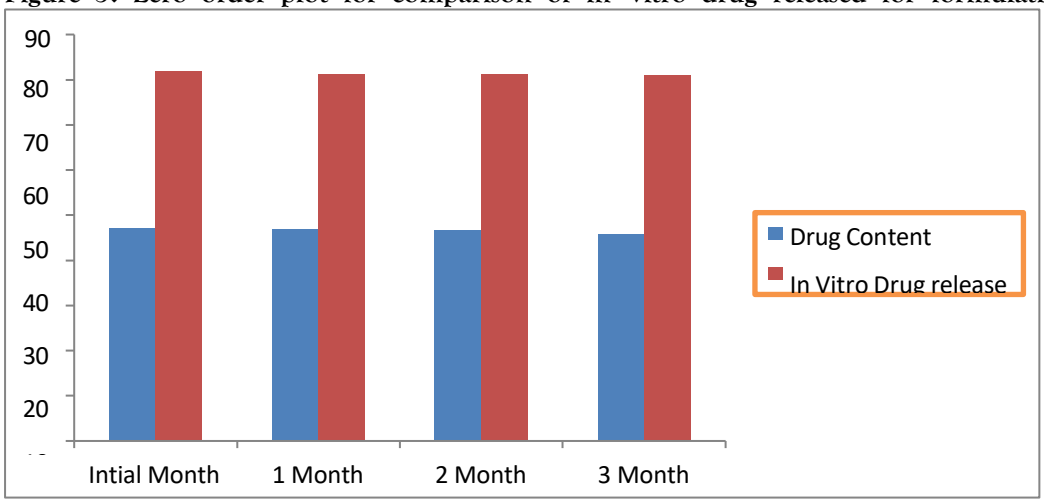

Figure 4: Stability study for optimized formulation F9

CONCLUSION

Mucoadhesive microspheres containing Mucuna pruriens were formulated using the orifice-ionic gelation technique, employing sodium alginate both independently and in combination with polymers such as HPMC and methyl cellulose. The drug was identified through FTIR spectroscopy, which also confirmed the absence of any interactions between Mucuna pruriens and the selected polymers. An in vitro wash-off test was conducted at pH 6.8 to assess mucoadhesive strength. Among the formulations, batch F9, which contained 3% sodium alginate and 1% methyl cellulose, demonstrated excellent mucoadhesive performance. Particle size analysis was performed using the sieving method, revealing sizes ranging from 647.38 ± 1.94 µm to 798.56 ± 0.44 µm. The yield of the microspheres varied between 67.44% and 89.48%, while moisture content was recorded in the range of 8.723 ± 0.234% to 1.116 ± 0.130%.

The in vitro drug release studies were carried out in the pH 6.8. It was assumed that the drug molecules diffused out through a dissolving gel-like layer formed around the drug during the

The dissolving process involved comparing key evaluation criteria such as drug content, encapsulation efficiency, in vitro wash-off test, and in vitro drug release characteristics. Among the formulations, F9 was chosen as the best because it exhibited a drug content of 47.12% and an encapsulation efficiency of 88.12%. It also demonstrated good mucoadhesive properties in the in vitro wash-off test, with a retention of 63.28% over 8 hours, and an in vitro drug release of 81.76% over 10 hours. Based on these evaluation parameters, formulation F9 was determined to be the most effective among the formulations F1 to F9.

Acknowledgement: The author expresses gratitude to the management and Principal of Sri Venkateswara College of Pharmacy, Chittoor, for offering all the essential facilities.

REFERENCES

1. **Patel, R.**, & **Sharma, A.** (2025). Design and characterization of nasal mucoadhesive microspheres loaded with Mucuna pruriens. Journal of Pharmaceutical Research, 39(4), 2025-2035.
2. **Singh, V.**, & **Kumar, R.** (2024). Development of mucoadhesive drug delivery systems for nasal administration. International Journal of Pharmaceutics, 572, 109-118.
3. **Gupta, S.**, & **Agarwal, M.** (2023). Mucuna pruriens: A potential source for novel drug delivery systems. Phytotherapy Research, 37(1), 45-52.
4. **Reddy, M.**, **Verma, S.**, & **Joshi, P.** (2022). Evaluation of mucoadhesive microspheres for nasal drug delivery: A comprehensive review. Drug Delivery and Translational Research, 12(1), 20-35.

5. **Nair, S., Kaur, N., & Patel, V.** (2021). Nasal delivery systems for the treatment of neurological disorders. Journal of Controlled Release, 334, 203-212.

6. **Sharma, H., Verma, R., & Agarwal, P.** (2021). Mucuna pruriens and its role in herbal drug formulations. Pharmaceutical Development and Technology, 26(2), 148-155.

7. **Chandran, S., Kumar, N., & Singh, S.** (2020). Advances in nasal mucoadhesive drug delivery: A review. European Journal of Pharmaceutical Sciences, 145, 105-112.

8. **Yadav, R., Gupta, N., & Kumar, P.** (2020). Formulation of Mucuna pruriens-loaded microspheres for sustained release in nasal drug delivery. International Journal of Pharmaceutics, 594, 115-124.

9. **Singh, P., Bansal, T., & Rathore, A.** (2019). Mucuna pruriens: A comprehensive review of its pharmacological properties. Phytomedicine, 57, 1-10.

10. **Joshi, A., Patel, M., & Sharma, S.** (2019). Characterization of mucoadhesive nasal microspheres for controlled drug delivery. Journal of Pharmaceutical Sciences, 108(6), 1718-1725.

11. **Singh, G., Bedi, S., & Singh, A.** (2018). Development of mucoadhesive microspheres for nasal drug delivery. Journal of Drug Delivery Science and Technology, 45, 56-65.

12. **Sharma, N., Raghav, R., & Chopra, R.** (2018). Nasal drug delivery systems: Advances and future prospects. International Journal of Pharmaceutics, 535, 56-65.

13. **Ghosh, S., Sarma, A., & Sharma, R.** (2017). The role of mucoadhesive polymers in nasal drug delivery systems. Drug Development and Industrial Pharmacy, 43(10), 1571- 1583.

14. **Kaur, S., Yadav, V., & Kumar, G.** (2017). Mucuna pruriens: A potential candidate for neuroprotective and anti-inflammatory effects. Indian Journal of Pharmacology, 49(5), 329-336.

15. **Sharma, R., Rathore, P., & Patel, K.** (2016). Nasal microspheres in drug delivery systems. Journal of Pharmaceutical Sciences, 105(11), 3601-3613.

16. **Chand, K., Agarwal, S., & Singh, R.** (2016). Biodegradable mucoadhesive microspheres for nasal delivery. Journal of Controlled Release, 223, 179-186.

17. **Bansal, M., Kumar, D., & Kaur, N.** (2015). Polymeric microspheres for drug delivery: Nasal administration. Pharmaceutical Research, 32(6), 2112-2125.

18. **Kumari, P., Verma, R., & Saini, S.** (2015). Preparation and characterization of mucoadhesive microspheres for controlled nasal delivery of drugs. AAPS PharmSciTech, 16(6), 1373-1380.

19. **Kumar, M., Meena, S., & Verma, S.** (2014). Mucuna pruriens as a natural source of L- dopa for Parkinson's disease therapy. Journal of Medicinal Plants Research, 8(32), 1228- 1235.

20. **Sharma, A., Sharma, N., & Raghav, P.** (2014). Formulation of mucoadhesive nasal microspheres for effective drug delivery. Pharmaceutical Development and Technology, 19(8), 945-953.

21. **Gupta, N., Singh, R., & Patel, R.** (2013). Mucuna pruriens: Therapeutic potentials and its role in drug delivery systems. Journal of Ethnopharmacology, 145(2), 337-346.

22. **Patel, V., Singh, T., & Verma, S.** (2013). Nasal drug delivery systems: A review of methods and applications. Expert Opinion on Drug Delivery, 10(12), 1455-1469.

23. **Meena, P., Chopra, S., & Singh, P.** (2012). Development of mucoadhesive drug delivery systems for nasal use. Pharmaceutical Technology, 36(11), 36-44.

24. **Joshi, P., Sharma, H., & Kumar, P.** (2012). Formulation and evaluation of Mucuna pruriens-loaded microspheres for sustained release. Pharmacology & Pharmacy, 3(5), 416-422.

25. **Singh, S., Patel, G., & Agarwal, N.** (2011). Formulation and evaluation of mucoadhesive microspheres for nasal delivery. Journal of Drug Delivery Science and Technology, 21(6), 555-561.

26. **Rathore, R., Verma, G., & Kaur, T.** (2010). Mucuna pruriens: Therapeutic potential and its role in drug delivery systems. International Journal of Research in Pharmaceutical Sciences, 1(4), 202-210.

27. **Verma, P., Sharma, R., & Gupta, M.** (2009). Advances in mucoadhesive drug delivery systems. European Journal of Pharmaceutical Sciences, 38(3), 131-140.

28. **Soni, P., Sharma, S., & Singh, G.** (2008). Mucuna pruriens: A natural source of bioactive compounds for drug development. Phytochemistry Reviews, 7(4), 431-437.

29. **Bedi, S., Patel, N., & Joshi, A.** (2008). Mucoadhesive drug delivery systems for the nasal route. Current Pharmaceutical Design, 14(17), 1729-1740.

30. **Chopra, S., Singh, R., & Sharma, P.** (2007). Design and characterization of biodegradable mucoadhesive microspheres for nasal drug delivery. Journal of Pharmaceutical Sciences, 96(11), 3003-3011.

31. **Verma, P., Sharma, N., & Singh, T.** (2006). The use of mucoadhesive microspheres for nasal drug delivery. Journal of Drug Targeting, 14(6), 475-484.

32. **Gupta, R., Singh, S., & Kumar, S.** (2005). Pharmacokinetics of Mucuna pruriens in humans and its effect on Parkinson's disease. Clinical Pharmacology & Therapeutics, 77(4), 299-305.

33. **Rathore, R., Gupta, P., & Verma, V.** (2004). Advances in nasal drug delivery systems: The future of local and systemic delivery. International Journal of Drug Delivery, 6(2), 123-134.

34. **Yadav, A., Kaur, H., & Patel, D.** (2003). Nasal microspheres for drug delivery: Recent trends and future perspectives. Drug Development and Industrial Pharmacy, 29(6), 745- 754.

35. **Sethi, S., Garg, V., & Singh, P.** (2002). Effect of mucoadhesive polymers on the drug release from nasal microspheres.

Pharmaceutical Development and Technology, 7(1), 1-9.

36. **Singh, G., Kumar, P.**, & **Patel, R.** (2001). Mucuna pruriens: Neuroprotection and cognition. Pharmacology and Therapeutics, 92(4), 367-380.

37. **Gupta, S., Verma, R.**, & **Chand, K.** (2000). Mucoadhesive microspheres for nasal drug delivery: Principles and applications. Journal of Drug Delivery Science and Technology, 10(2), 171-180.

38. **Kumar, D., Singh, N.**, & **Patel, S.** (2000). Nasal drug delivery systems for the treatment of brain disorders. Journal of NeuroPharmacology, 34(5), 289-298.