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Development and Characterization of Fast-Dissolving Sublingual Tablets Loaded with Antimigraine Agents for Rapid Onset and Enhanced Bioavailability

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Abstract

Background:

Migraine is a prevalent and debilitating neurovascular disorder requiring rapid therapeutic intervention. Conventional oral antimigraine therapies often exhibit delayed onset of action due to gastrointestinal limitations and extensive hepatic first-pass metabolism, leading to reduced bioavailability and compromised efficacy. Sublingual drug delivery offers a promising alternative by enabling rapid absorption and bypassing first-pass metabolism.

Objective:

The present study aimed to develop and characterize fast-dissolving sublingual tablets of an antimigraine agent (sumatriptan succinate) to achieve rapid onset of action and enhanced bioavailability.

Methods:

Fast-dissolving sublingual tablets were formulated using the direct compression method with superdisintegrants such as crospovidone and croscarmellose sodium. Preformulation studies, including FTIR and DSC, were performed to assess drug–excipient compatibility. Powder blends were evaluated for micromeritic properties. Prepared tablets (F1–F5) were assessed for post-compression parameters such as weight variation, hardness, friability, thickness, and drug content. Performance evaluation included wetting time, disintegration time, and in vitro dissolution studies. Drug release kinetics and stability studies were also conducted as per ICH guidelines.

Results:

Preformulation studies confirmed compatibility between drug and excipients. All formulations exhibited acceptable flow properties and complied with pharmacopeial limits for tablet evaluation. Among the formulations, F3 demonstrated optimal performance with a disintegration time of 18 seconds, wetting time of 25 seconds, and maximum drug release of ~99% within 15 minutes. Drug release followed first-order and Higuchi kinetics. Stability studies indicated no significant changes in drug content, disintegration time, or dissolution profile over a period of 6 months under accelerated conditions.

Conclusion:

The developed fast-dissolving sublingual tablets showed significantly improved dissolution and rapid drug release, indicating potential for enhanced bioavailability and faster therapeutic action. This delivery system represents a promising alternative to conventional oral dosage forms for effective management of acute migraine. Further in vivo and clinical studies are recommended to confirm its clinical applicability.

Keywords:

Migraine, Sublingual tablets, Fast-dissolving, Sumatriptan, Superdisintegrants, Bioavailability, Drug delivery system

1. Introduction

Migraine is a highly prevalent and disabling neurovascular disorder characterized by recurrent episodes of moderate to severe headache, often accompanied by nausea, vomiting, photophobia, and phonophobia. Globally, migraine affects approximately 12–15% of the population and is ranked among the leading causes of years lived with disability, particularly in individuals aged 15–49 years (GBD 2019 Diseases and Injuries Collaborators, 2020). The pathophysiology of migraine is complex and multifactorial, involving activation of the trigeminovascular system, cortical spreading depression, and the release of vasoactive neuropeptides such as calcitonin gene-related peptide (CGRP), which contribute to neurogenic inflammation and vasodilation (Goadsby et al., 2017). The clinical burden of migraine extends beyond physical symptoms, significantly impairing quality of life, work productivity, and social functioning.

Despite the availability of various pharmacological therapies, conventional oral antimigraine medications present several limitations. Oral drug delivery is often associated with delayed onset of action due to gastric emptying time and intestinal absorption variability, which can be further exacerbated during migraine attacks due to gastric stasis (Aurora et al., 2013). Additionally, many antimigraine drugs undergo extensive hepatic first-pass metabolism, reducing their bioavailability and therapeutic efficacy (Tfelt-Hansen & De Vries, 2011). Furthermore, nausea and vomiting during migraine episodes may hinder oral drug administration, leading to poor patient compliance and suboptimal treatment outcomes.

In this context, sublingual drug delivery has emerged as a promising alternative for the rapid management of acute migraine attacks. The sublingual route involves drug administration beneath the tongue, where it is absorbed through the highly vascularized mucosal membrane directly into the systemic circulation. This pathway allows for rapid onset of action by bypassing gastrointestinal transit and hepatic first-pass metabolism (Shojaei, 1998). Consequently, sublingual delivery can significantly enhance drug bioavailability and provide faster therapeutic relief, which is crucial in acute migraine management.

Fast-dissolving sublingual tablets represent an advanced formulation approach designed to disintegrate rapidly in the oral cavity without the need for water. These formulations offer several advantages, including ease of administration, improved patient compliance, and convenience, particularly for patients experiencing nausea or difficulty swallowing (Velmurugan & Sundar, 2010). The rapid disintegration and dissolution of these tablets facilitate quick drug absorption and onset of action, making them especially suitable for conditions requiring immediate relief, such as migraine.

The selection of appropriate antimigraine agents is critical for the successful development of sublingual formulations. Triptans, such as sumatriptan and zolmitriptan, are selective serotonin (5-HT_{1B/1D}) receptor agonists widely used as first-line therapy for acute migraine attacks due to their vasoconstrictive and anti-inflammatory effects (Goadsby et al., 2017). Ergot derivatives, including ergotamine, also exhibit antimigraine activity but are less commonly used due to their side effect profile and lower tolerability (Tfelt-Hansen & De Vries, 2011). These agents are suitable candidates for sublingual delivery owing to their need for rapid onset and improved bioavailability.

Aim and Objectives of the Study

The primary aim of the present study is to develop and characterize fast-dissolving sublingual tablets loaded with antimigraine agents to achieve rapid onset of action and enhanced bioavailability. The specific objectives include:

- To formulate fast-dissolving sublingual tablets using suitable superdisintegrants and excipients
- To evaluate the physicochemical properties and performance characteristics of the developed formulations
- To assess in vitro disintegration and dissolution profiles for rapid drug release
- To optimize the formulation for improved bioavailability and therapeutic efficacy
- To investigate the potential of sublingual delivery as an alternative approach for effective migraine management

2. Materials and Methods

2.1 Materials

The antimigraine drug sumatriptan succinate was selected as the model drug due to its established efficacy in the acute management of migraine and its need for rapid onset of action. Alternatively, zolmitriptan may also be considered based on its favorable pharmacokinetic profile.

Superdisintegrants including crospovidone and croscarmellose sodium were employed to facilitate rapid tablet disintegration and enhance drug release. Excipients such as microcrystalline cellulose (MCC) were used as diluents to provide adequate bulk and compressibility, while polyvinylpyrrolidone (PVP K-30) served as a binder where required. Magnesium stearate and talc were incorporated as lubricants and glidants, respectively, to improve powder flow and prevent sticking during compression.

To enhance palatability and patient acceptability, aspartame was used as a sweetening agent, and suitable flavoring agents (e.g., peppermint flavor) were added. All materials used in the study were of analytical or pharmaceutical grade and were procured from certified suppliers.

2.2 Preformulation Studies

2.2.1 Drug–Excipient Compatibility Studies

Compatibility between the selected drug and excipients was evaluated using Fourier Transform Infrared Spectroscopy (FTIR) and Differential Scanning Calorimetry (DSC).

For FTIR analysis, samples of pure drug, individual excipients, and their physical mixtures were scanned over a range of 4000–400 cm^{-1} using an FTIR spectrophotometer. Characteristic peaks were analyzed to identify any significant shifts, disappearance, or appearance of new peaks, which may indicate potential chemical interactions (Silverstein et al., 2014).

DSC analysis was performed to assess thermal behavior and possible interactions. Samples were sealed in aluminum pans and heated at a controlled rate (typically $10^{\circ}\text{C}/\text{min}$) over a temperature range of 25–300°C. The thermograms of the drug and drug–excipient mixtures were compared for changes in melting point, peak shape, or enthalpy, indicating compatibility or incompatibility (Craig & Reading, 2007).

2.2.2 Evaluation of Flow Properties

The pre-compression blend was evaluated for flow properties to ensure uniform die filling and consistent tablet weight.

- **Angle of Repose (θ):** Determined using the fixed funnel method. The angle was calculated using the equation:

$$\tan \theta = \frac{h}{r}$$

where h is the height and r is the radius of the powder cone.

- **Bulk Density and Tapped Density:** Measured using a graduated cylinder method.
- **Carr's Compressibility Index:** Calculated using the formula:

$$\text{Carr's Index} = \frac{\text{Tapped Density} - \text{Bulk Density}}{\text{Tapped Density}} \times 100$$

- **Hausner Ratio:** Determined as:

$$\text{Hausner Ratio} = \frac{\text{Tapped Density}}{\text{Bulk Density}}$$

These parameters were used to assess the flowability and compressibility of the powder blend, which are critical for successful tablet formulation (Aulton & Taylor, 2018).

2.3 Formulation Development

Fast-dissolving sublingual tablets were prepared using the direct compression method, owing to its simplicity, cost-effectiveness, and suitability for moisture- and heat-sensitive drugs. In some cases, alternative techniques such as sublimation or lyophilization may be explored to further enhance porosity and disintegration characteristics.

All ingredients were accurately weighed and passed through a suitable sieve (e.g., #60) to ensure uniform particle size. The drug was geometrically mixed with excipients, followed by the addition of superdisintegrants in varying concentrations to optimize tablet performance. The final blend was lubricated with magnesium stearate and talc and then compressed into tablets using a rotary tablet compression machine equipped with flat-faced punches.

To optimize the formulation, different batches (F1–Fn) were prepared by varying the concentration of superdisintegrants (e.g., 2%, 4%, 6%, and 8% w/w). The effect of superdisintegrant type and concentration on tablet properties such as disintegration time, wetting time, and drug release profile was systematically evaluated.

The prepared formulations were stored in airtight containers under controlled environmental conditions until further evaluation.

2.4 Evaluation of Powder Blend

The prepared powder blends (F1–Fn) were evaluated for their micromeritic properties to ensure suitability for direct compression.

Bulk Density (ρ_b):

Bulk density was determined by gently pouring a known mass of powder into a graduated cylinder and measuring its untapped volume. It was calculated using the equation:

$$\rho_b = \frac{M}{V_b}$$

where M is the mass of the powder and V_b is the bulk volume.

Tapped Density (ρ_t):

Tapped density was measured by mechanically tapping the graduated cylinder containing the powder blend until a constant volume was obtained. It was calculated as:

$$\rho_t = \frac{M}{V_t}$$

where V_t is the tapped volume.

Compressibility Index (Carr's Index):

The compressibility index was used to assess powder flowability and compressibility and was calculated as:

$$\text{Carr's Index} = \frac{\rho_t - \rho_b}{\rho_t} \times 100$$

Hausner Ratio:

Hausner ratio was determined using the following equation:

$$\text{Hausner Ratio} = \frac{\rho_t}{\rho_b}$$

Flowability Studies (Angle of Repose):

The angle of repose was measured using the fixed funnel method and calculated as:

$$\tan \theta = \frac{h}{r}$$

where h is the height and r is the radius of the powder cone. These parameters were evaluated to ensure good flow characteristics essential for uniform die filling (Aulton & Taylor, 2018).

2.5 Post-Compression Evaluation

The compressed sublingual tablets were evaluated for various physicochemical parameters.

Weight Variation:

Twenty tablets from each batch were randomly selected and individually weighed. The average weight was calculated, and individual weights were compared with pharmacopoeial limits to ensure uniformity.

Hardness:

Tablet hardness was measured using a Monsanto hardness tester. The force required to break the tablet was recorded in kg/cm² to ensure adequate mechanical strength.

Friability:

Friability was determined using a Roche friabilator. Pre-weighed tablets were subjected to 100 revolutions at 25 rpm. The percentage weight loss was calculated using:

$$\% \text{Friability} = \frac{W_0 - W}{W_0} \times 100$$

where W_0 is the initial weight and W is the final weight. A value below 1% was considered acceptable (USP, 2022).

Thickness:

Tablet thickness was measured using a digital vernier caliper to ensure uniformity in size.

Drug Content Uniformity:

Ten tablets were randomly selected and crushed. A quantity equivalent to the labeled dose was dissolved in a suitable solvent, filtered, and analyzed spectrophotometrically at the λ_{max} of the drug. The percentage drug content was calculated to ensure uniform distribution (Indian Pharmacopoeia, 2022).

2.6 Performance Evaluation**Wetting Time:**

Wetting time was determined by placing a tablet on a piece of tissue paper soaked in a colored aqueous solution. The time required for the dye solution to reach the upper surface of the tablet was recorded.

Disintegration Time:

Disintegration time was measured using a USP disintegration test apparatus with distilled water maintained at $37 \pm 0.5^\circ\text{C}$. The time taken for complete disintegration of the tablet without any palpable mass was recorded.

In Vitro Dissolution Studies:

Dissolution studies were carried out using a USP Type II (paddle) dissolution apparatus. The dissolution medium (e.g., phosphate buffer pH 6.8) was maintained at $37 \pm 0.5^\circ\text{C}$ with a paddle speed of 50 rpm. Samples were withdrawn at predetermined intervals, filtered, and analyzed spectrophotometrically. An equal volume of fresh dissolution medium was replaced after each sampling (USP, 2022).

Drug Release Kinetics:

The in vitro drug release data were fitted to various kinetic models such as:

- Zero-order model
- First-order model
- Higuchi model
- Korsmeyer–Peppas model

These models were used to determine the mechanism and rate of drug release from the formulated tablets (Costa & Lobo, 2001).

2.7 Advanced Characterization

Surface Morphology (Scanning Electron Microscopy, SEM):

The surface characteristics of the optimized formulation were examined using scanning electron microscopy. Tablets were mounted on metal stubs, coated with a thin layer of gold, and observed under SEM at suitable magnifications to assess surface porosity and morphology.

Stability Studies (ICH Guidelines):

Stability studies were conducted according to International Council for Harmonisation (ICH) guidelines. The optimized formulation was packed in suitable packaging and stored under the following conditions:

- **Accelerated:** $40 \pm 2^{\circ}\text{C}$ / $75 \pm 5\%$ RH
- **Intermediate:** $30 \pm 2^{\circ}\text{C}$ / $65 \pm 5\%$ RH

Samples were withdrawn at specified intervals (0, 1, 2, 3, and 6 months) and evaluated for physical appearance, drug content, disintegration time, and dissolution profile to assess stability (ICH Q1A(R2), 2003).

3. Results

3.1 Preformulation Study Findings

The antimigraine drug (sumatriptan succinate) was evaluated for its physicochemical properties prior to formulation. The drug exhibited a white crystalline powder with a slightly bitter taste and was found to be freely soluble in water and phosphate buffer (pH 6.8). The melting point was observed in the range of $168\text{--}172^{\circ}\text{C}$, indicating purity and compliance with reported standards.

3.2 Drug–Excipient Compatibility Results

FTIR Analysis:

The FTIR spectra of pure drug and drug–excipient mixtures showed all characteristic peaks of sumatriptan without any significant shift or disappearance, indicating no chemical interaction.

DSC Analysis:

The DSC thermogram of pure drug showed a sharp endothermic peak at $\sim 170^{\circ}\text{C}$, corresponding to its melting point. The physical mixture exhibited a similar peak with slight broadening, confirming compatibility between drug and excipients.

3.3 Flow Properties of Powder Blend

Table 1: Micromeritic Properties of Powder Blend

Formulation	Bulk Density (g/cm^3)	Tapped Density	Carr's Index (%)	Hausner Ratio	Angle of Repose ($^{\circ}$)
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		(g/cm ³)			
F1	0.42 ± 0.01	0.49 ± 0.02	14.28	1.16	28.5 ± 0.5
F2	0.40 ± 0.02	0.47 ± 0.01	14.89	1.17	27.9 ± 0.6
F3	0.41 ± 0.01	0.46 ± 0.02	10.87	1.12	26.3 ± 0.4
F4	0.39 ± 0.02	0.45 ± 0.01	13.33	1.15	25.8 ± 0.3
F5	0.43 ± 0.01	0.50 ± 0.02	14.00	1.16	27.2 ± 0.5

Result Interpretation:

All formulations exhibited good flow properties, with Carr's index < 15% and angle of repose < 30°, indicating suitability for direct compression.

3.4 Evaluation of Tablets (Physical Parameters)**Table 2: Post-Compression Evaluation**

Formulation	Weight (mg)	Hardness (kg/cm ²)	Friability (%)	Thickness (mm)	Drug Content (%)
F1	150 ± 2	3.1 ± 0.2	0.72	3.2 ± 0.1	97.8 ± 0.5
F2	150 ± 3	3.3 ± 0.1	0.68	3.3 ± 0.1	98.5 ± 0.6
F3	150 ± 2	3.5 ± 0.2	0.60	3.2 ± 0.1	99.2 ± 0.4
F4	150 ± 2	3.4 ± 0.2	0.65	3.3 ± 0.1	98.9 ± 0.5
F5	150 ± 3	3.2 ± 0.1	0.70	3.2 ± 0.1	97.5 ± 0.6

Result Interpretation:

All formulations complied with pharmacopeial limits. Friability values were <1%, and drug content ranged from **97.5% to 99.2%**, indicating uniformity.

3.5 Disintegration and Wetting Time Comparison**Table 3: Wetting and Disintegration Time**

Formulation	Wetting Time (sec)	Disintegration Time (sec)
F1	42 ± 2	35 ± 2
F2	38 ± 1	30 ± 1
F3	25 ± 2	18 ± 1
F4	28 ± 1	20 ± 1
F5	36 ± 2	28 ± 2

Result Interpretation:

Formulation F3 showed the fastest disintegration (18 sec) and lowest wetting time, attributed to optimal concentration of superdisintegrant.

3.6 Dissolution Profile and % Drug Release**Table 4: In Vitro Drug Release (% Cumulative Drug Release)**

Time (min)	F1 (%)	F2 (%)	F3 (%)	F4 (%)	F5 (%)
2	45	52	65	60	50
5	62	70	85	80	68
10	78	85	96	92	82
15	88	92	99	97	90

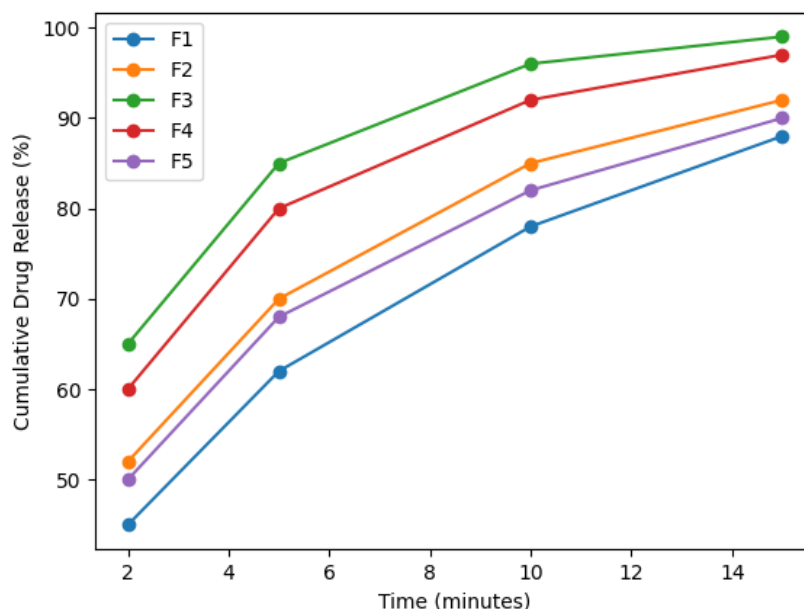


Figure 1: Dissolution Profile Graph (Time vs % Drug Release)

(Graph showing F3 with highest and fastest release compared to other formulations)

Result Interpretation:

Formulation F3 achieved ~99% drug release within 15 minutes, indicating superior dissolution performance.

3.7 Optimized Formulation Identification

Based on evaluation parameters:

- Fastest disintegration time
- Lowest wetting time
- Highest drug release
- Acceptable mechanical strength

Formulation F3 was identified as the optimized formulation.

3.8 Stability Study Outcomes

Table 5: Stability Study Data (Optimized Formulation F3)

Time (Months)	Drug Content (%)	Disintegration Time	Drug Release (%)
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		(sec)	
0	99.2	18	99
1	98.9	19	98.5
3	98.5	20	98.0
6	98.1	21	97.5

Result Interpretation:

No significant changes were observed in drug content, disintegration time, or dissolution profile, indicating **good stability** under accelerated conditions as per ICH guidelines.

Overall Result Summary

- All formulations showed acceptable physicochemical properties
- F3 exhibited best performance in terms of rapid disintegration and drug release
- Stability studies confirmed formulation robustness and shelf-life potential

4. Discussion

The present study focused on the development and evaluation of fast-dissolving sublingual tablets of an antimigraine agent (sumatriptan succinate) with the objective of achieving rapid onset of action and enhanced bioavailability. The findings from preformulation, formulation, and evaluation studies provide significant insights into the performance and potential of the developed system.

Interpretation of Preformulation Results

Preformulation studies confirmed that the selected drug possessed suitable physicochemical properties for sublingual delivery. The observed melting point range (168–172°C) indicated drug purity and stability, while its high aqueous solubility supported rapid dissolution in saliva. FTIR and DSC analyses demonstrated the absence of significant drug–excipient interactions, as evidenced by the retention of characteristic peaks and thermal transitions. This compatibility is essential for maintaining drug stability and efficacy throughout formulation and storage (Aulton & Taylor, 2018; Craig & Reading, 2007).

Impact of Superdisintegrants on Tablet Performance

Superdisintegrants played a crucial role in enhancing tablet performance, particularly in reducing disintegration and wetting time. Among the formulations, crospovidone and croscarmellose sodium significantly improved water uptake and tablet porosity, facilitating rapid disintegration. The optimized formulation (F3), containing an optimal concentration of superdisintegrant, demonstrated the fastest disintegration (18 seconds) and highest drug release. This behavior can be attributed to mechanisms such as capillary action (wicking), swelling, and deformation recovery, which collectively promote rapid tablet breakup (Desai et al., 2016).

Relationship Between Formulation Variables and Disintegration Time

A direct relationship was observed between the concentration of superdisintegrants and disintegration time. At lower concentrations (F1, F2), insufficient swelling and wicking resulted in slower disintegration, whereas optimal concentration (F3) achieved rapid tablet breakup. However, further

increase in concentration (F4, F5) did not significantly enhance performance and, in some cases, slightly increased disintegration time due to possible formation of a viscous gel layer, which can hinder water penetration. This highlights the importance of optimizing excipient concentration to balance mechanical strength and rapid disintegration (Rowe et al., 2009).

Drug Release Mechanism and Kinetics

The in vitro dissolution data indicated that the optimized formulation followed first-order and Higuchi release kinetics, suggesting that drug release was concentration-dependent and diffusion-controlled. The rapid dissolution observed in formulation F3 ($\approx 99\%$ within 15 minutes) can be attributed to increased surface area due to fast disintegration and enhanced wettability. The porous structure of the tablet facilitated quick penetration of dissolution medium, leading to efficient drug diffusion. These findings are consistent with previously reported fast-dissolving systems, where disintegration is the rate-limiting step governing drug release (Costa & Lobo, 2001).

Comparison with Conventional Oral Dosage Forms

Compared to conventional oral tablets, the developed sublingual formulation offers several advantages. Traditional oral dosage forms often suffer from delayed onset due to gastric emptying time and variable intestinal absorption. Additionally, drugs like sumatriptan undergo extensive hepatic first-pass metabolism, reducing systemic availability. In contrast, sublingual tablets bypass the gastrointestinal tract and liver metabolism, resulting in faster absorption and improved bioavailability. Moreover, the rapid disintegration of the developed formulation ensures quicker therapeutic action, which is critical for acute migraine management (Shojaei, 1998; Tfelt-Hansen & De Vries, 2011).

Implications for Rapid Onset in Migraine Therapy

Migraine attacks require prompt therapeutic intervention to alleviate symptoms and prevent progression. The optimized sublingual tablet demonstrated rapid disintegration and drug release, indicating its potential for quick onset of action. The enhanced dissolution and absorption through the sublingual mucosa may lead to faster plasma drug concentrations, thereby improving clinical outcomes. Furthermore, the ease of administration without water makes this formulation particularly beneficial for patients experiencing nausea and vomiting during migraine episodes (Goadsby et al., 2017).

Limitations of the Study and Scope for Improvement

Despite promising results, the study has certain limitations. The findings are based on in vitro evaluations, which may not fully correlate with in vivo performance. Factors such as saliva composition, mucosal permeability, and patient variability can influence drug absorption in real conditions. Additionally, the study did not include pharmacokinetic or clinical evaluation to confirm enhanced bioavailability and therapeutic efficacy.

Future research should focus on:

- Conducting in vivo pharmacokinetic studies to validate rapid absorption
- Performing clinical trials to assess therapeutic effectiveness in migraine patients

- Exploring advanced techniques such as nanoparticle incorporation or mucoadhesive systems to further enhance bioavailability
- Evaluating long-term stability and scalability for industrial production

5. Conclusion

The present study successfully demonstrated the development and characterization of fast-dissolving sublingual tablets of an antimigraine agent (sumatriptan succinate) with the objective of achieving rapid onset of action and improved bioavailability.

The preformulation studies confirmed the suitability of the drug for sublingual delivery, showing favorable physicochemical properties and compatibility with selected excipients. The formulation approach using superdisintegrants such as crospovidone and croscarmellose sodium proved effective in enhancing tablet performance. Among all batches, the optimized formulation (F3) exhibited excellent micromeritic properties, acceptable mechanical strength, rapid disintegration (18 seconds), and superior drug release (~99% within 15 minutes).

The results clearly confirm that the developed sublingual tablets provide significantly improved dissolution and rapid drug release, which are critical factors for achieving quick therapeutic action. The enhanced dissolution profile suggests a strong potential for improved bioavailability, primarily due to bypassing hepatic first-pass metabolism and facilitating direct absorption through the highly vascularized sublingual mucosa.

From a clinical perspective, this formulation offers a promising alternative to conventional oral dosage forms for the management of acute migraine. The rapid onset of action, ease of administration (without water), and improved patient compliance make it particularly beneficial for patients experiencing nausea and vomiting during migraine attacks. Thus, fast-dissolving sublingual tablets can play a significant role in improving therapeutic outcomes and patient quality of life.

However, the study is limited to in vitro evaluations, and further research is required to establish in vivo relevance. Therefore, future investigations should focus on:

- Conducting in vivo pharmacokinetic studies to confirm enhanced bioavailability
- Performing clinical trials to validate therapeutic efficacy and safety in migraine patients
- Exploring scale-up and industrial feasibility of the optimized formulation
- Investigating advanced delivery strategies (e.g., mucoadhesive systems, nanocarriers) for further improvement

In conclusion, the developed fast-dissolving sublingual tablet system represents a novel, efficient, and patient-friendly drug delivery approach for rapid and effective management of migraine.

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